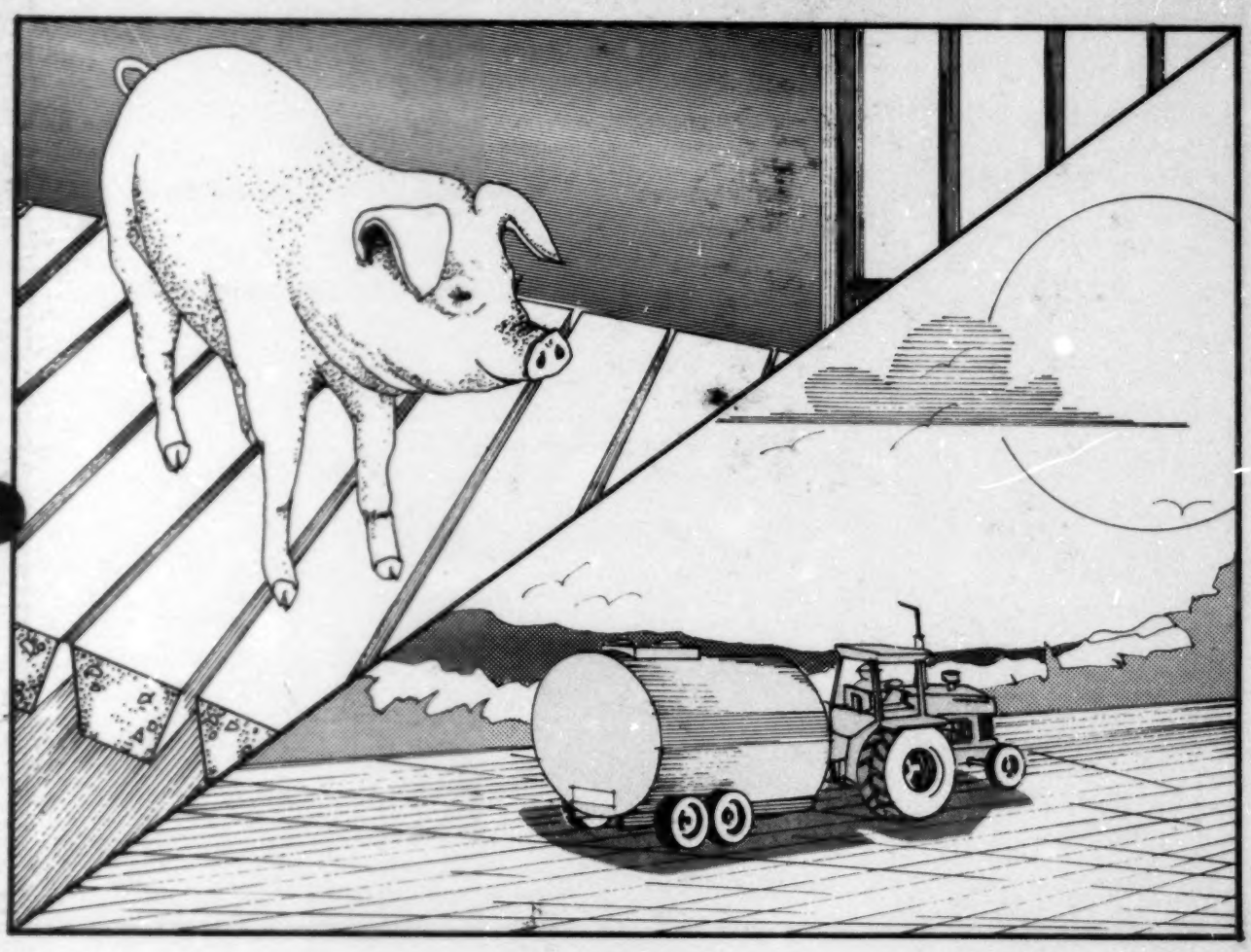
SWINE MANURE HANDLING SYSTEMS



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SWINE MANURE HANDLING SYSTEMS

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INTRODUCTION

The objective of this publication is to outline alternative manure handling systems for the benefit of hog farmers who are planning new facilities, expanding their operation or remodelling existing barns.

Public sensitivity to the environmental impacts of large quantities of manure, as well as the rising cost of fertilizer, energy and feed have all served to focus attention on manure as either a possible nuisance or a valuable resource. Manure management, therefore, has become a very important part of the entire livestock and crop production system.

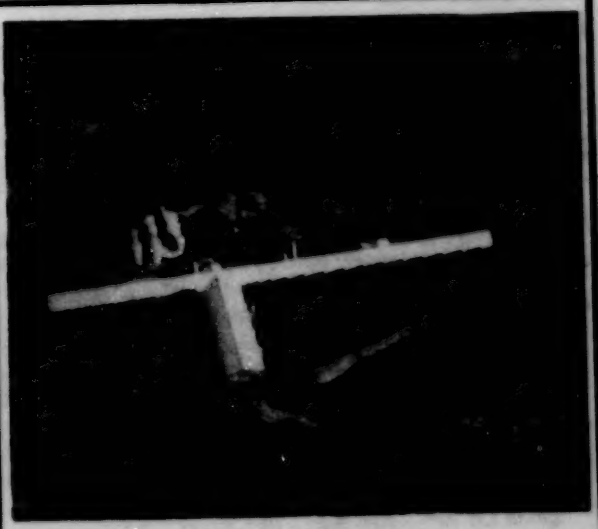
PLANNING AND SITING SWINE FACILITIES

Larger and more intensive piggeries in areas of increasing population and urbanization require improved planning and siting to minimize conflict with neighboring land uses. The important considerations relating to the planning and siting of a new or expanded piggery are:

Starting a Project

Consider all alternatives: Whether expanding, remodelling or rebuilding, look at all available management options relating to manure handling and manure disposal alternatives. Keep facilities and management systems simple.

Consider legal requirements: Consider your location in relation to surface and groundwater sources and the possible impact your operations may have on water resources. If you are expanding an existing operation that is not ideally located, work towards a more acceptable overall operation. Whatever system is chosen must be compatible with building codes and land use by-laws.



Intensively housed swine require a well planned manure handling system.

Plan for the future: Will today's planning be acceptable in five or ten years? Can you expand easily, mechanize or automate in the future? Allow for equipment repair and maintenance, vacations, sickness and future changes in technology and farm management. Avoid complex, specialized equipment which may have only limited use or be unreliable in the future.

Get help: There are many people available to help in making planning decisions. Swine specialists, district and regional extension specialists, as well as regional agricultural engineers are available to help. Other successful swine farmers are also a valuable source of information. Equipment manufacturers and industry magazines may also be helpful.

Guidelines for Siting

Odor and nuisance: Unfortunately, totally odor-free swine facilities are not economically feasible at the present time. Siting, that is, having regard to neighbors and respecting adjoining land uses, is very important in establishing a good neighbor policy. Siting criteria have been developed based on the "minimum distance separation" (MDS) concept which is part of the Confinement Livestock Manure Management Code of Practice. This approach takes into consideration factors specific to the piggery as well as the neighboring land use in recommending a separation distance. For example, the setbacks required with various neighboring land uses are shown in Table 1. Further details of the MDS calculation can be obtained from the Code of Practice or your regional agricultural engineer.

TABLE 1. THE MINIMUM DISTANCE SEPARATION SUGGESTED FOR THE SITING OF NEW FARROW-TO FINISH OPERATIONS

Adjacent Land Use	50 Sow	100 Sow	200 Sow
Urban residential, institutional	722 m	898 m	1109 m
Large scale country residential	451 m	560 m	693 m
Low use recreational, industrial	361 m	448 m	554 m
Nearest neighbour	316 m	392 m	485 m

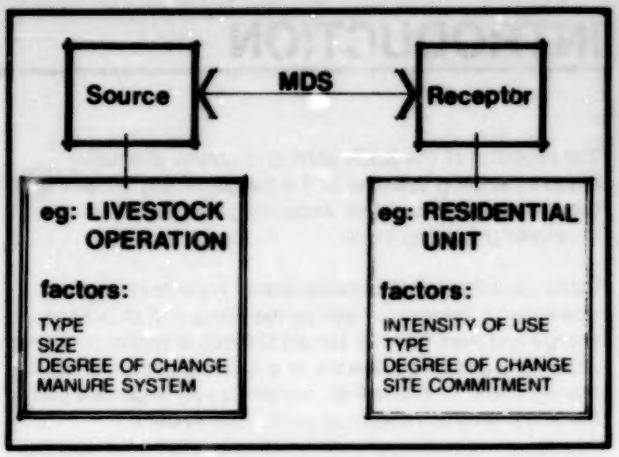


Figure 1 – The Minimum Distance Separation between a source and receptor is determined on a site specific basis involving many factors.

Adequate land base: The most practical method of manure disposal is to have it utilized by crops. Piggeries must have access to sufficient land to allow manure to be applied at recommended rates.

Access: All components of the manure handling system should be accessible by appropriate equipment. All weather roads to the storage area will facilitate manure transport regardless of weather and soil conditions.

Topography: Wherever possible, the swine housing area and manure storage facility should be located so as to permit the use of gravity flow transfer. Surface water should be directed away from the building sites and manure storage areas. Contaminated drainage from open pens or manure storages should be contained on the owner's property.

Water table: The increasing demand put on groundwater supplies underlines the importance of protecting this resource from contamination. One or two test holes to determine the depth to the static water table and soil conditions will greatly aid in selecting suitable manure storage sites.

PHYSICAL AND BIOLOGICAL PROPERTIES

The volume of manure produced by the pigs and storage volumes to plan for are given in the following table:

TABLE 2. MANURE STORAGE VOLUMES

Class of Swine	Manure Production L/(pig/day)	Required Storage for liquid manure* L/(pig/day)	Required Storage for solid manure L/(pig/day)
20-90 kg (8-22 weeks)	5.1	7.1	7.1
5-10 kg (3- 6 weeks)	1.1	1.6	
10-25 kg (6- 9 weeks)	2.3	3.1	
25-35 kg (9-12 weeks)	3.4	4.8	
35-60 kg (12-16 weeks)	5.1	7.1	
60-80 kg (16-20 weeks)	7.4	10.2	
80-90 kg (20-22 weeks)	9.1	12.7	
Dry Sow	11.3	15.9	13.6
Nursing sow and litter			
(wean at 3 weeks	15.6	21.8	
(wean at 6 weeks)	19.5	27.5	

*This column is calculated from 'manure production' by multiplying it by a factor of 1.4 to allow for spillage from waterers, floor washing, and dilution water where required.

References: Canadian Code for Farm Buildings, 1977
Mid-West Plan Service Structures and Environment Handbook, 1977

The calculation and design of storages is discussed later in this publication.

Physical Properties

Hog manure is loosely referred to as being solid, semi-solid or liquid, depending upon its consistency and moisture content. Where bedding is used or where the manure is subjected to natural or induced air drying, **solid manure** is produced. It is stiff and nonflowing and can be handled by conventional solid manure handling equipment such as slat and chain conveyors, front end loaders and box spreaders. **Semi-solid** manure is often very difficult to handle since it may be too thick to pump and too thin to handle with a front end loader. Modified equipment may be required to handle this manure or it may be simpler to modify the management system so that either liquid or solid manure is assured. This may require improved feeding equipment, the addition of water, the increased or reduced use of bedding, or many other approaches to alter the manure's physical characteristics to make for easier handling. Solids/liquid separation techniques may be employed to yield solid and liquid fractions.

Where animal management practices exclude or restrict the use of bedding, **liquid manure** is produced by the addition of dilution water (also wash water or leaky waterers). Manure with a moisture content of 85-90% is a semi-solid that will flow by gravity from deep gutters; at 90% or greater water content it can be pumped.

Unfortunately, a piggery does not necessarily produce a liquid or a solid manure but perhaps a manure with a consistency somewhere in between. The quantity of bedding used, degree of drying by exposure to the air, amount of water leakage by watering bowls, method of storage, amount of wash water, whether or not a sprinkler system is used, and feed wastage, all affect the type of manure produced.

Biological Properties

Hog manure is a very concentrated organic material. Microbial decomposition begins immediately after it is voided by the animal. The organic matter is broken down to simpler compounds, the process being characterized by the production of numerous gases. If the decomposition takes place in the presence of oxygen (O_2), the process is said to be aerobic and; when it occurs in the absence of O_2, the process is called anaerobic. Most manure storages are anaerobic. Anaerobic decomposition is typical of liquid manure handling systems and characteristic of collection pits, holding tanks and storage lagoons.

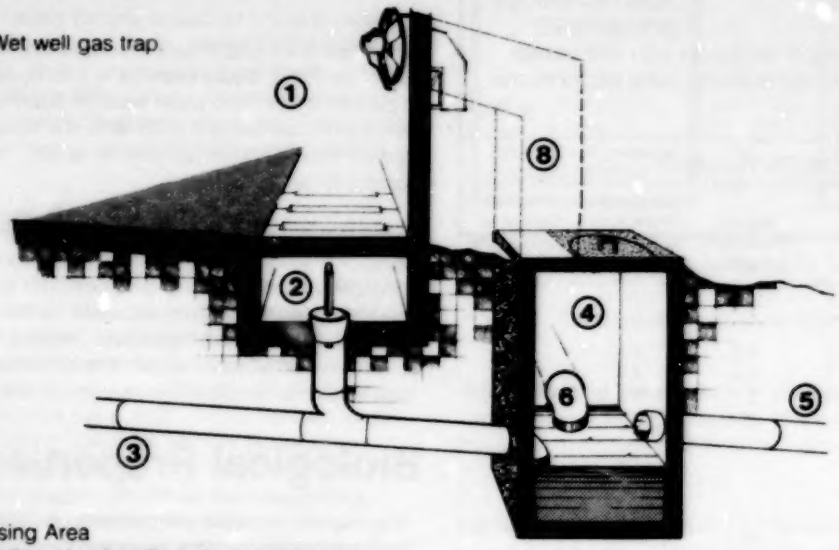
Aerobic decomposition is essentially an odorless process, whereas anaerobic decomposition produces noxious odors. In addition, anaerobic decomposition can produce gases which are potentially hazardous to man and animals. These include carbon dioxide (CO_2), methane (CH_4), ammonia (NH_3), and hydrogen sulfide (H_2S).

Carbon dioxide(CO_2) is seldom a critical problem in animal housing. Instances have occurred where failure of the mechanical ventilation system in a tightly constructed barn has resulted in animal deaths, but they are probably due to a combination of heat stress and oxygen deficiency rather than CO_2 asphyxiation. An alarm system to warn the operator in the event of such a failure would be a prudent investment.

Methane(CH_4) is unlikely to be a factor in animal health and performance in normally ventilated buildings. It is, however, potentially flammable and explosive in nature. At low concentrations, it burns with a pale blue flame, but at high concentrations there is a real danger of an explosion. The head space of a covered manure storage is where explosive concentrations may collect. To minimize the risks from CH_4 in

and around manure handling and storage facilities, prohibit smoking or the use of naked flames, use explosion-proof electric motors on fans and equipment, adequately vent covered storages to outside air, and use U-bends or gas traps (see Figure 2) in all sewage channels connecting a barn to outside storage tanks so gases in the tank cannot back up into the barn. Ensure that a barn with inside manure storage is continuously ventilated (if unventilated for even a short period, thoroughly vent before use).

Figure 2a – Wet well gas trap



① Animal Housing Area
② Pail plug. Hollow pipe handle acts as emergency overflow prevents plug popping when other barn gutters are drained
③ Gravity drainage. 200 mm minimum pipe.
④ Wet well. Collection point for multiple barn drainage systems.
⑤ Gravity drainage to storage. 200 mm minimum pipe size.
⑥ 90 degree elbows insure submerged pipe inlets to wet well
⑦ in-ground covered storage
⑧ Optional ventilation of wet well

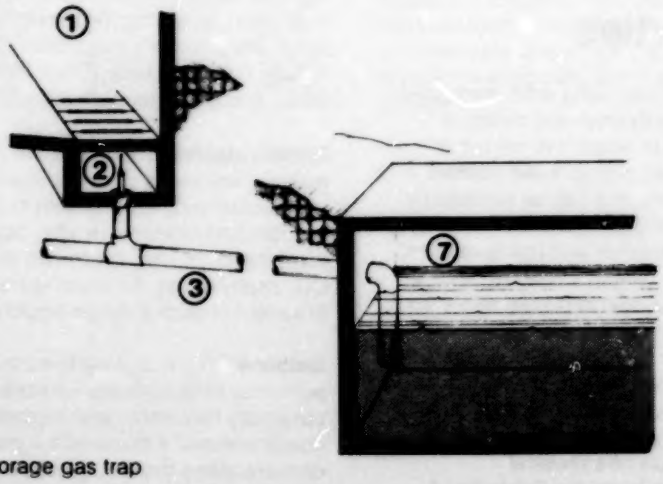


Figure 2b – Barn to storage gas trap

Figure 2a and 2b – Gas traps

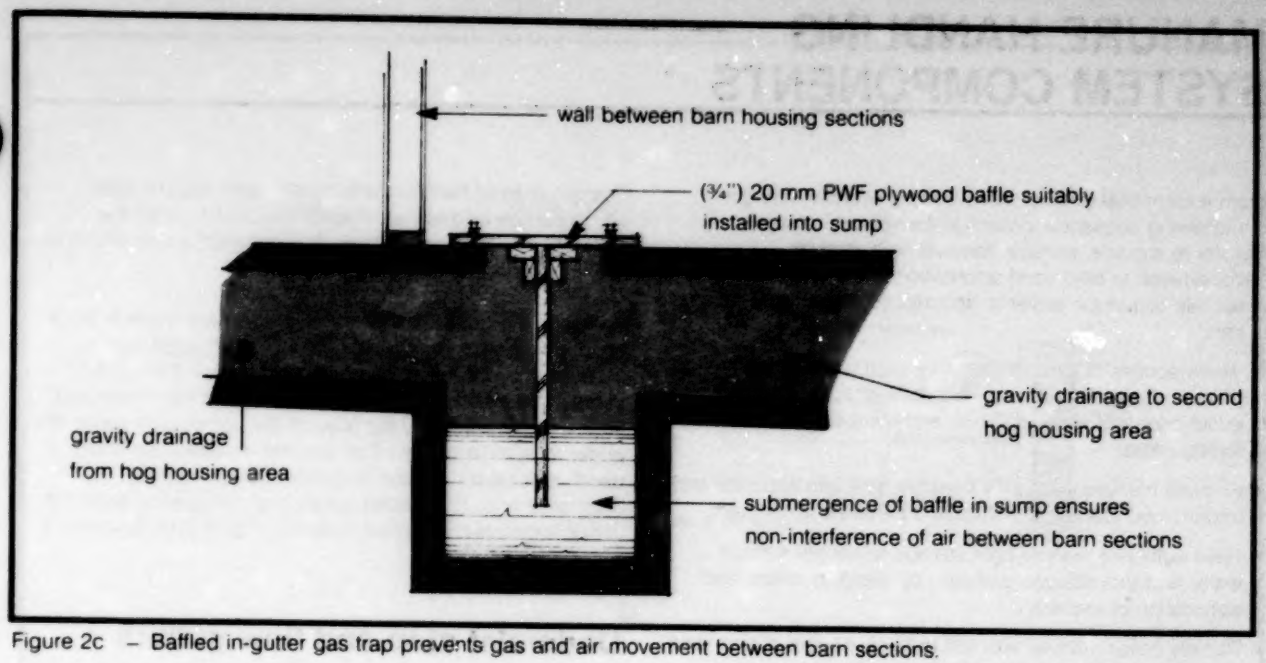

wall between barn housing sections
(¾") 20 mm PWF plywood baffle suitably installed into sump
gravity drainage to second hog housing area
gravity drainage from hog housing area
submergence of baffle in sump ensures non-interference of air between barn sections

Figure 2c – Baffled in-gutter gas trap prevents gas and air movement between barn sections.

Ammonia, with its sharp pungent odor, acts as an irritant to moist tissues such as eyes and the respiratory tract even at relatively low concentrations. Low concentrations, readily detectable to humans, appear to adversely affect animal health and performance in the presence of other atmospheric contaminants such as dust and H_2S. Dangerously high or even moderate concentrations in the animal environment are not a concern, as these have not been found. Rapid manure removal from the barn, adequate floor slopes to ensure good drainage, liberal use of bedding and increased ventilation rates (particularly during the emptying of manure storages) are possible methods of reducing concentrations.

Hydrogen sulphide(H_2S) is potentially the most dangerous of the manure gases. It has killed both humans and animals in Canada and many other countries. Constant exposure to concentrations of only a few parts per million, or short exposure to higher concentrations also are thought to be detrimental to animal well-being. Normally, H_2S is barely detectable in animal housing as long as the liquid manure remains undisturbed. Odor is not a good indicator because high concentrations may numb the sense of smell. Even slight agitation of storages or disturbance of gutters will release H_2S to the atmosphere.

Manure gases have caused fatalities involving both humans and animals, as well as property damage and loss. Such accidents are the result of high concentrations of toxic gases accumulating under certain conditions. These conditions occur infrequently and are usually recognizable, therefore, they are preventable.

Concentrations appear to depend on the length of time the manure is stored and the degree of agitation or disturbance. The greatest risks are during emptying of tanks and pits, when H_2S in the pithead space and above slats can reach lethal levels within a few minutes. To minimize risks from this gas, do not agitate the manure when emptying pits located within a building. At the same time provide maximum ventilation, remove stock from a building when agitation is necessary (or, if stock cannot be moved, make use of a windy day to ensure a maximum air exchange through open doors and windows), use gas traps in sewage channels between covered outside pits and barns to prevent gas back-up, and empty pits freqently, particularly in warm weather.

MANURE HANDLING SYSTEM COMPONENTS

From a functional point of view, manure systems operate in the following sequence: collection (temporary storage), transfer to storage, storage, removal from storage, transportation to land, land application and incorporation. To make this sequence easier to accomplish, keep these factors in mind:

- Have access to sufficient land for crop utilization of manure. Controlling the rate and time of application will avoid odor and water pollution and will result in maximum fertility value.
- Remove manure frequently from the barn into separate and undisturbed storage to minimize odor levels in the barn.
- Have sufficient manure-tight storage to control surface water and groundwater pollution by avoiding winter land application of manure.
- Rapidly cover manure with soil to control odors during land spreading and to maximize fertilizer value of manure.
- Use an approved method of dead animal disposal.

Collection Methods

Deep narrow gutters

Deep narrow gutters are used mainly in remodelling situations since little floor disturbance is required. The principle of this collection method is to develop a deep narrow column of liquid manure in order to obtain effective flushing action when the gutter is drained.

Advantages:

- inexpensive
- adaptable to remodelled solid floor barns
- minimizes in-barn storage (1-2 days).

Disadvantages:

- pen sanitation difficult because of large portions of solid concrete floor
- higher ammonia levels because of exposed wet solid floors.

The gutter may be located along the outside walls or down the centre of the barn, depending which way the pens slope. Gutters along the outside of the barn may interfere with the barn footings unless they are constructed just inside the foundation. The standard dimensions of this gutter type are shown in Figure 3. The walls and floors should be tied together with reinforcing steel to ensure against cracking.

The gutter must be fitted with a water-tight plug or gate which can be opened as often as required to drain the contents into the storage tank. This is called a stop-and-flow flushing system of emptying the gutter.

Baffles in the gutter are recommended where a solids build-up is anticipated. Removable baffles constructed from plywood may be installed at approximately 4.0 m (12 ft.) intervals. A clearance of about 150-200 mm from the gutter floor is suggested. The purpose of the baffles is to cause the gutter to flush in stages. This ensures an adequate liquid depth to flush the section of gutter farthest from the discharge end. The baffles create high turbulence along the gutter floor reducing solids build-up. Figure 3(b) illustrates a baffle installation.

Underslat stop and flow gutters

Rectangular underslat gutters

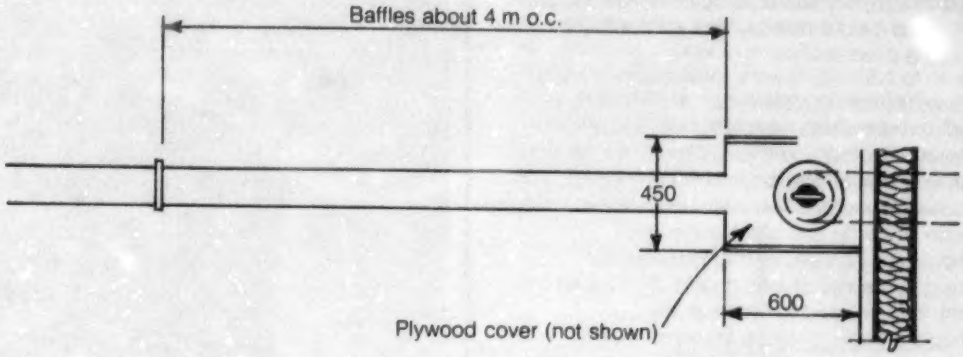
Slatted floor systems have been widely accepted and are used for all phases of the swine operation. The major advantage of slatted floors for swine housing is a reduction in the amount of hand labor required for manure removal. This system consists of a flat bottomed trench or channel under the slatted area. At one end of the gutter a plug(s) leads to a gravity transfer pipe having a minimum diameter of 200 mm (8 in.).

To begin operation the gutter outlet is plugged and primed with 25 to 50 mm (1 to 2 in.) of water. The plug is left in place and the manure allowed to accumulate in the gutter until it is 100 to 150 mm (4 to 6 in.) from the top. The plug is then pulled and the wastes rapidly flow out of the gutter through the sewer line to storage. The plug is replaced and the cycle repeated. Gutters should be drained one at a time.

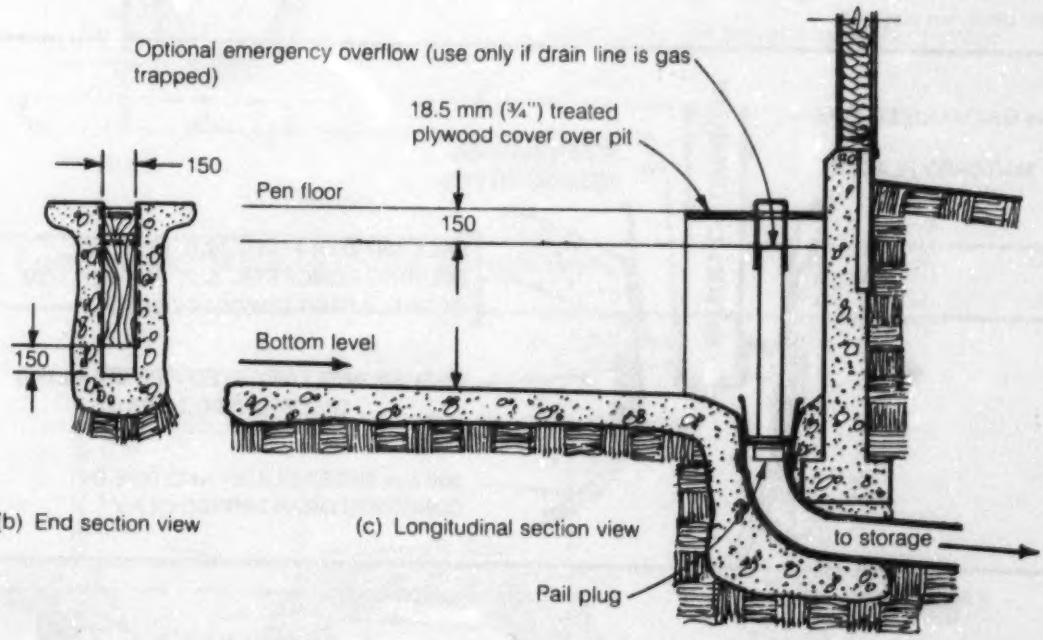
The length of time between draining depends upon the type of animals housed, the depth and width of the gutter and the amount of waste or wash water added. Typical draining frequencies are three to six weeks in farrowing and nursery facilities and one to two weeks in feeder and dry sow facilities.

Gutter depths vary with overall gutter length. Gutters less than 10 m (30 ft) long should be 450 mm (18 in.) deep. Gutters from 10 to 30 m (30 to 100 ft) should be constructed 600 mm (24 in.) deep. Avoid gutters longer than 30 m. However, if necessary, deepen them to 750 mm (30 in.).

It is important that stop-and-flow gutter bottoms be constructed level across their width and length. A slope on the gutter floor may cause solid-liquid separation during filling and emptying, hampering complete cleanout.



(a) Plan view



(b) End section view

(c) Longitudinal section view

dimensions in mm

Figure 3 – Deep narrow gutter design details

Rapid flushing ensures that solids are transported with the liquids, therefore, large plugs and large sewer lines are needed. Normally, 200 to 250 mm (8 to 10 in.) sewer lines sloped one per cent convey waste from the collection gutters to storage. Plugs can be farm-fabricated from available materials such as matching plastic pails shown in Figure 4. Alternatively premanufactured plugs can be obtained from pipe suppliers.

Gutter widths of up to 1.5 m (5 ft) work satisfactorily in feeder facilities. In dry sow facilities gutters wider than 1.2 m (4 ft) should be subdivided to provide narrower channels which can each be flushed separately to improve clean-out. Most gutters will clean very well to a distance of 20 to 25 m (65 to 82 ft) from the outlet. Although 100 to 150 mm (4 to 6 in.) of wastes may remain at the far end of the gutter, the accumulation should not increase with subsequent use. Provide an opening at the end of long gutters. This allows the dumping of a tank load of liquid to flush out any accumulation should it begin to cause problems. Some producers do this routinely once or twice yearly. Wide, short gutters such as those under farrowing crates or short rows of nursery pens will often not clean completely. Accumulations of solids remaining after flushing can be regularly washed down during crate and room washing. In these gutters the plugs should be located in one corner of the pit to make washing easier. Manure takeout should be located along the perimeter of the pit to allow emergency cleanout in the event that a pipe becomes clogged.

Large diameter (200 mm) pipe used as a drainage plug.

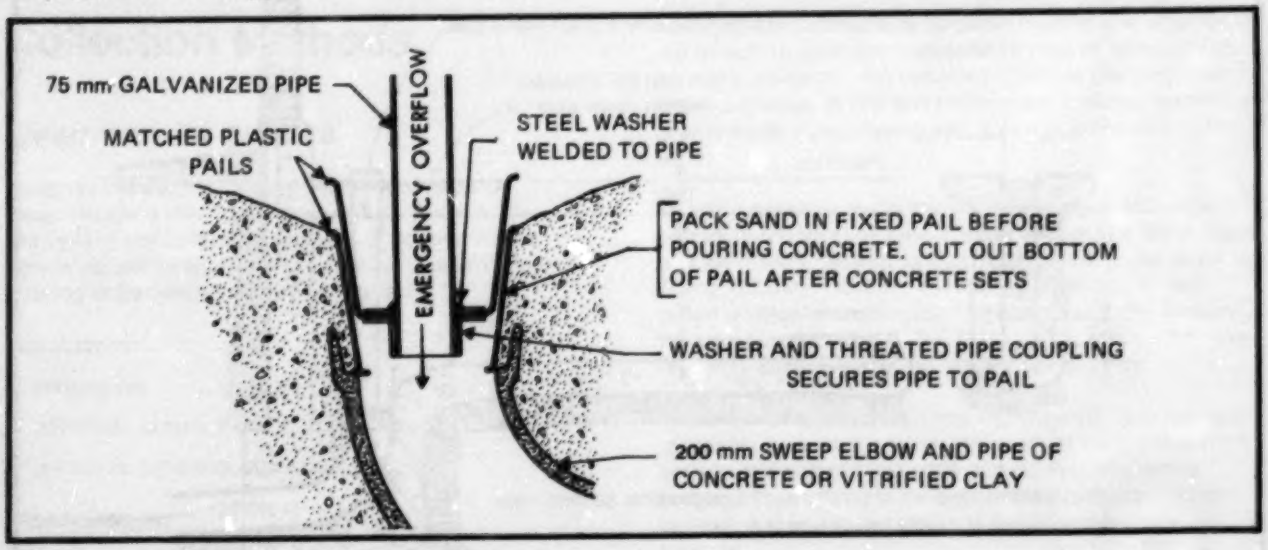

75 mm GALVANIZED PIPE
MATCHED PLASTIC PAILS
EMERGENCY OVERFLOW
STEEL WASHER WELDED TO PIPE
PACK SAND IN FIXED PAIL BEFORE POURING CONCRETE. CUT OUT BOTTOM OF PAIL AFTER CONCRETE SETS
WASHER AND THREATED PIPE COUPLING SECURES PIPE TO PAIL
200 mm SWEEP ELBOW AND PIPE OF CONCRETE OR VITRIFIED CLAY

Figure 4 – Pail plug detail.

Y gutters and V gutters

V and Y gutters allow more frequent flushing. With the steeply sloped sides, wastes are accumulated in a relatively deep narrow gutter and drained more often.

Construction of the Y gutter is the major problem. Concrete may be precast, cast or plastered into place. Many farmers hesitate to tackle this operation and commercial builders usually prefer more conventional construction methods. Occasionally, commercial plastic and fibreglass V gutters have appeared on the market. Many variations in Y and V gutter design and application exist. V gutters are simpler to construct.

Figures 5,6 and 7 illustrate basic design principles and applications. The V gutter should not exceed about 15 m (50 ft) in length for a gutter of 300 mm depth. For deeper gutters, 20 m is usually the maximum length. The top of the V or Y should be the same width as the pen slats. A slope of 1:500 (0.2%) is usually used in installing the gutter channels.The walls must be steep enough and smoothly finished to prevent manure build-up. Baffles may be considered in housing applications to improve manure drainage. Recommended slopes for the trench sides are:

¾:1 for nursery trenches
1:1 for farrowing and finisher trenches.

In-barn odors should be minimal because of the short-term storage and effective cleaning.

Most producers drain the Y gutters twice per week. The 750 mm gutter at a depth of 250 mm provides 90 L of storage per 1500 mm section or approximately 4 days manure storage for a sow and litter. The manure is drained to another building with a manure storage pit or to an outside holding tank or lagoon.

Additional water is not usually required for the gutters to drain satisfactorily. Some producers have reported the need for extra water during the winter. When only a few sows occupy the stalls over the gutter, extra water may be needed.

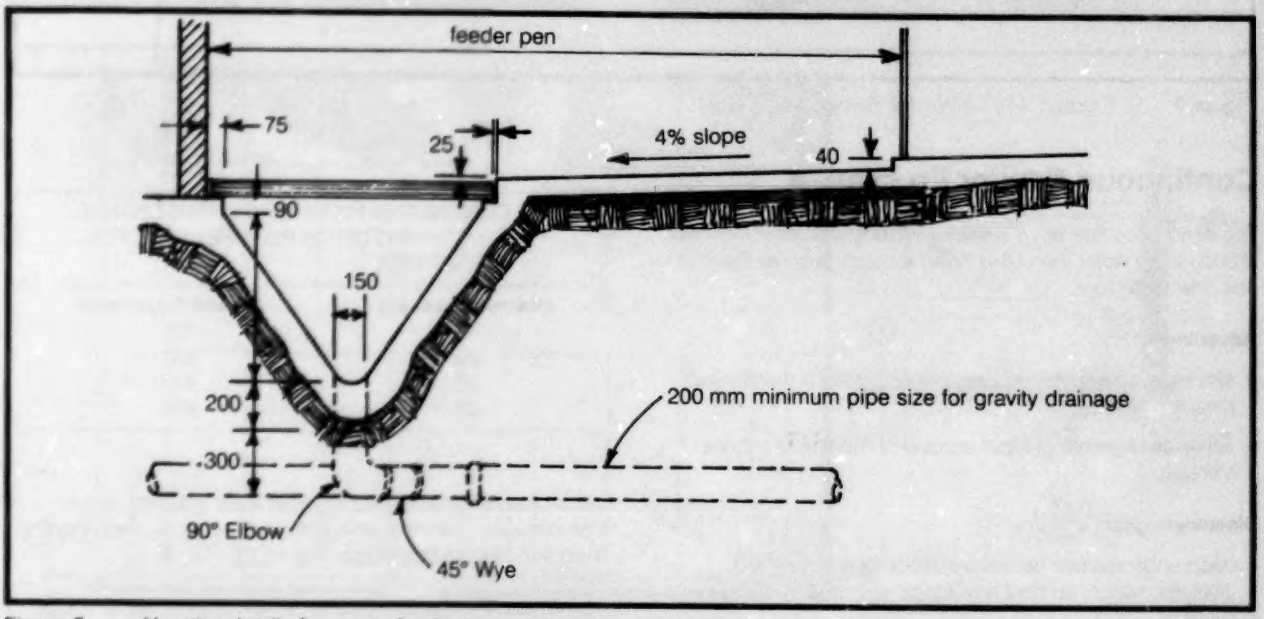


Figure 5 – V-gutter details for use in feeder barns (all dimensions in mm).

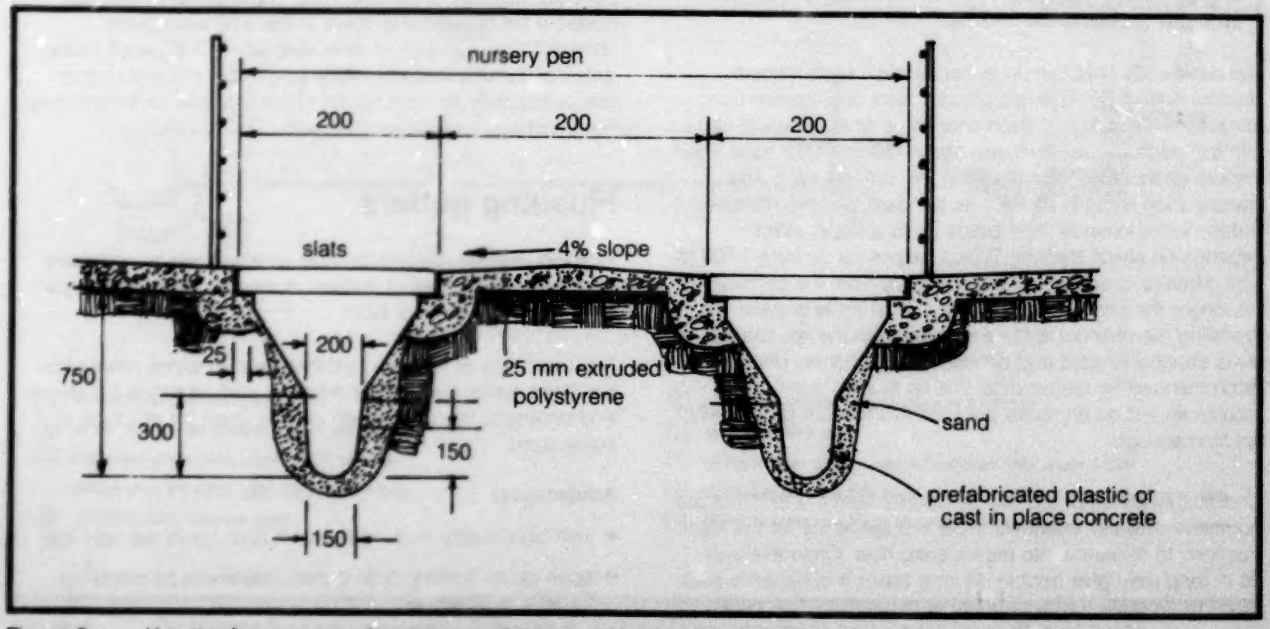


Figure 6 – Y-gutter for weaner or farrowing applications (all dimensions in mm).

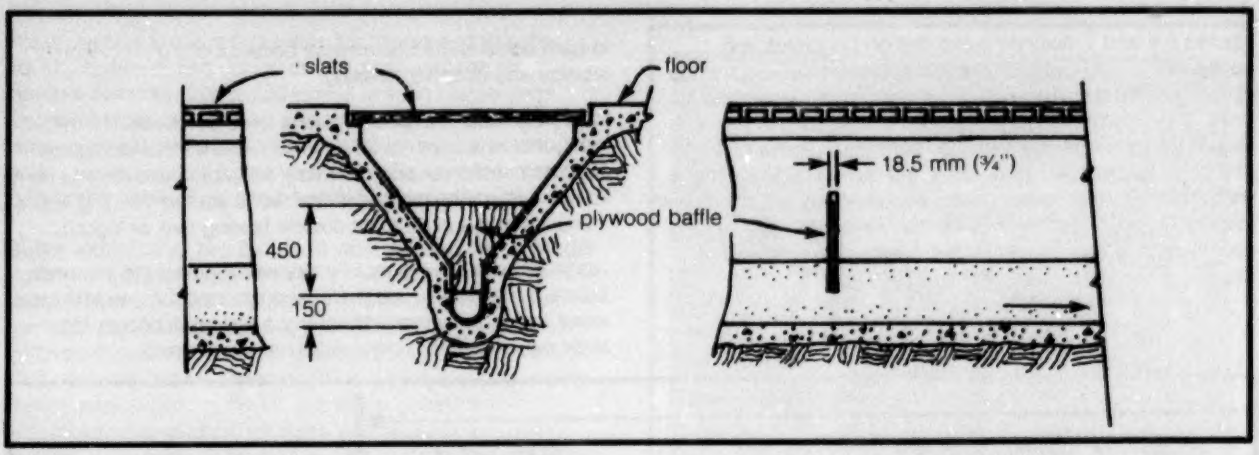


Figure 7 – Y-gutter with baffles (all dimensions in mm).

Continuous flow or lip system

The continuous flow or lip system functions well with much less dilution wash water than other liquid systems such as the stop and flow system.

Advantages:

- simple reliable system. Does not depend on a mechanical means of operation.
- achieves objective of rapid removal of manure to outside storage.

Disadvantages:

- deep underslat pits necessary where long gutters are involved, hence, no cost advantage over stop and flow systems.
- in-barn odors may not be reduced significantly, however, toxic gas problems are minimal.

The continuous flow system depends upon each manure channel bottom being made smooth, level and manure-tight. Across the outlet end of each channel, a small full-width weir with top edge exactly level and about 150 mm high traps liquid manure so that the channels never dry out and stick. The manure soon starts to trickle over the dam, and the manure surface in the channel then builds up to a slope, which depends on solids content. Typical slopes range from 1:100 to 1:30. Manure is deepest at the end away from the overflow; the longer the channel, the deeper it must be to prevent overfilling the channel at the end away from the lip. Table 3 gives channel lengths and corresponding channel depths recommended for feeder pigs. The lip system is not recommended for dry sows because this manure is generally not fluid enough.

Channel width is not too critical; widths from 1.0 to 2.4 m are common. In wider channels there is a tendency for the liquid fractions to separate into meandering flow. Channels over 25 m long may give trouble. In long barns it is better to step down to an outlet cross channel at mid-length. The outlet cross-channel should step down at least 300 mm deeper than the long channels, and it must have a gas trap where it flows into long-term storage (Figure 2).

TABLE 3. CONTINUOUS FLOW (LIP SYSTEM) CHANNEL LENGTH AND DEPTH REQUIREMENTS FOR FEEDER PIGS.

Channel Length (m)	Channel Depth (mm)
15	700
20	800
25	800
30	900

A small drain elbow and stopper in the channel bottoms just above each step illustrated in detail C in Figure 8, allows periodic drainage of the channels. Some owners have also added a set of vertical grooves in the side walls of the channels just upstream of each step where a plywood sluice-gate can be dropped into place across the channel to stop flow temporarily for flushing the channel above, or for servicing sewer connections below the step.

Flushing gutters

Flushing manure systems provide an alternative for operators who are seeking a rapid method of manure removal from the barn with a minimum of labor.

The two types of flushing systems used in swine production are open gutter flushing for finishing and gestation buildings, and underslat flushing, which can be used for any type of swine barn.

Advantages:

- with high quality flushing liquid, in-barn odors are very low
- open gutter flushing aids in pen cleanliness as manuring habits are reinforced

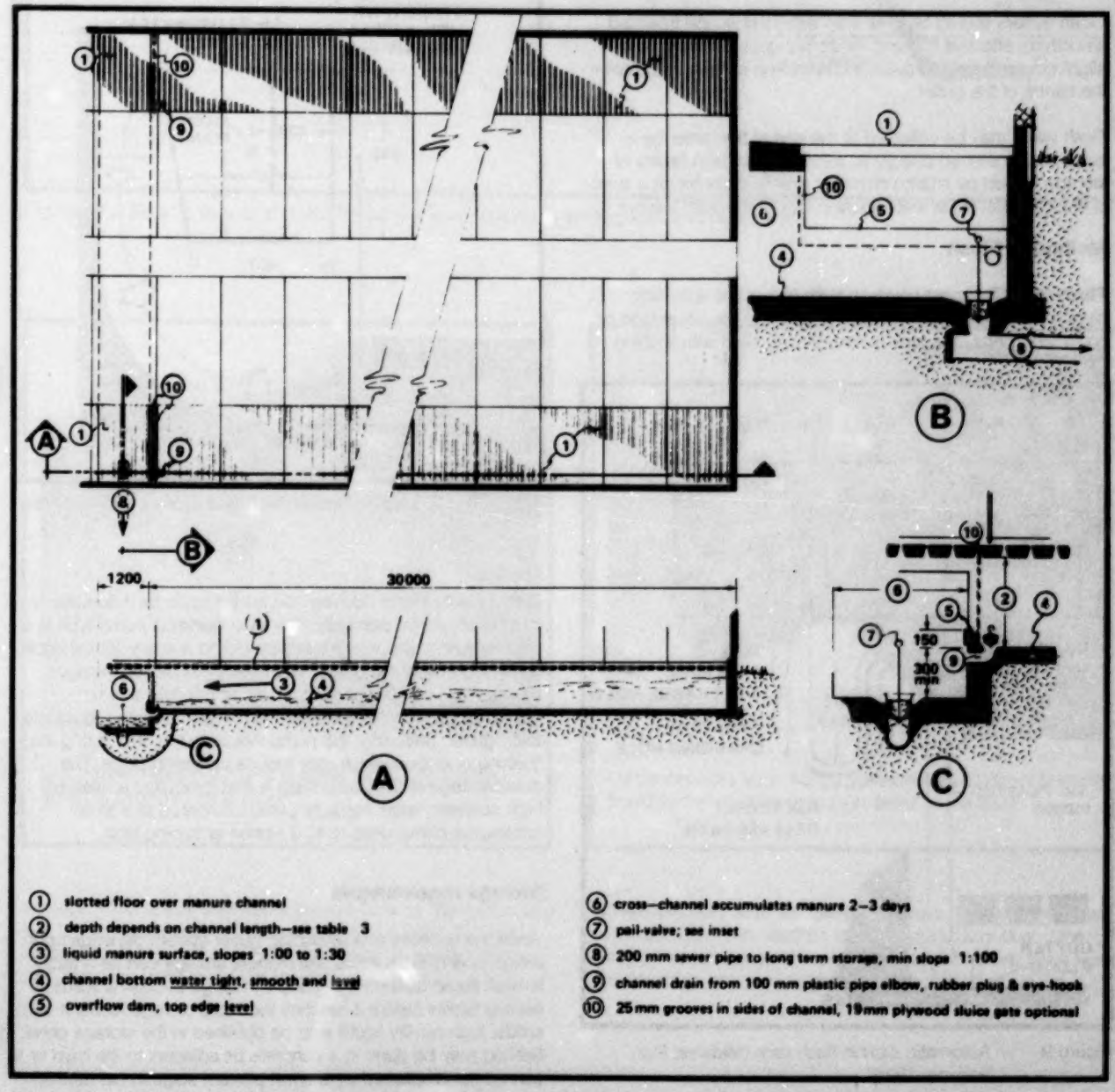
- lends itself to remodelling situations since floor disturbance is minimal
- reduced construction costs with open gutter system.

Disadvantages:

- maintaining high quality recycled manure for flushing may require more sophisticated storage and treatment sytems
- health implications with open gutters. Disease transmissions and recycled medication is possible
- high losses of fertilizer value
- increased maintenance problems with system equipment.

Flushing systems likely have the greatest appeal to those in farrow-to-finish operations who are committed to a liquid manure system and have a site suitable for open earthen, long term storage.

Debate exists regarding open gutter flushing versus underslat flushing. Much of the advantage concerning pen sanitation and improved manure habits may be be lost with underslat flushing. Underslat flushing achieves rapid removal of manure from the barn. Purchasers of feeder pigs may have some reservations about open-gutter flushing because of the possibility of disease transmission. Producers using medication should not use open-gutter systems for finishing hogs because of the potential for ingestion of drug residues.



① slotted floor over manure channel
② depth depends on channel length—see table 3
③ liquid manure surface, slopes 1:00 to 1:30
④ channel bottom water tight, smooth and level
⑤ overflow dam, top edge level
⑥ cross-channel accumulates manure 2–3 days
⑦ pail-valve; see inset
⑧ 200 mm sewer pipe to long term storage, min slope 1:100
⑨ channel drain from 100 mm plastic pipe elbow, rubber plug & eye-hook
⑩ 25 mm grooves in sides of channel, 19 mm plywood sluice gate optional

Figure 8 – Continuous flow manure system, adapted to a slotted-floor growing/finishing barn (ie. CPS plan 3428).

Flushing Gutter Design

Manure removal from the gutter depends upon velocity, depth, duration and frequency of the flush; and these factors are determined by the dimensions and slope of the gutter and by the rate of flush.

Whereas gutter slopes between 0.75 and 3% have been used successfully in Alberta, a slope of 1.0-1.5% is recommended. Gutter slope may be achieved by maintaining a level building and sloping the gutter or by sloping the entire building. Where short open gutters or long underslat gutters are involved, the former is recommended, however, the latter should be considered where long open gutters are desired.

Open gutters should be level from side to side and trowelled smooth for effective flushing. Underslat gutters may have a slight crown (5 mm) to prevent channelling of flush liquid down the centre of the gutter.

Flush water may be collected at the end of the gutter by a sump, or transferred directly to a solids separation facility or storage lagoon by a large diameter gravity drain line. If a sump is used, it must be at least equal in size to the flush volume.

Method of Flush

Flush tank: The most common flush tank is the automatic siphon tank (Figure 9). This type of tank has the advantage of no moving parts. The tank is continuously filled with flushing liquid; at a predetermined tank level the siphon triggers and the entire tank contents are discharged. Flush volume is determined by the tank size and the rate of flush by the siphon size.

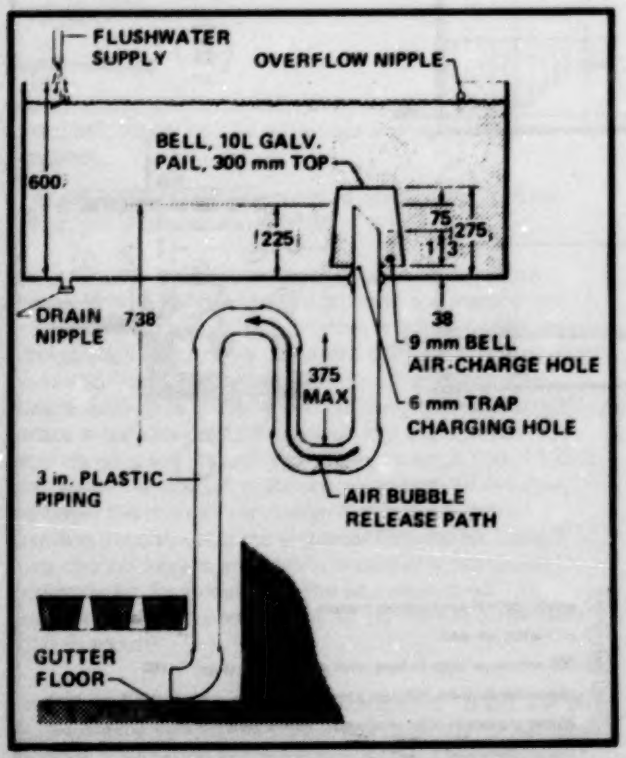


Figure 9 – Automatic siphon flush tank (Midwest Plan Service, 1976).

The other flushing tank method is the tipping tank (Figure 10). This tank pivots on its mounts and at a predetermined level it overbalances and dumps its contents at a very rapid rate. Design is critical in order to tip properly.

Frequency of flush is varied by controlling the rate of tank fill, or the tank can be flushed manually.

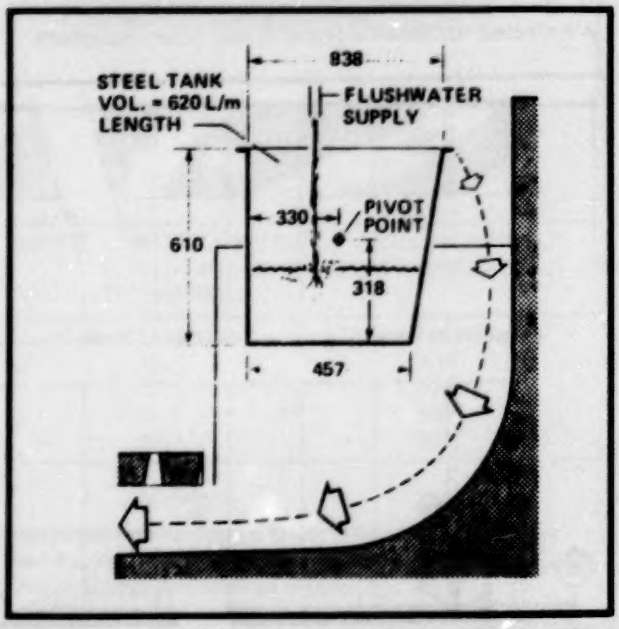


Figure 10 – Tipping bucket flush tank (Jones & Nye, 1976).

Pump flush: Pump flushing can be set up to be automatic or can be controlled manually. The most common pump type is a submersible pump which transfers stored manure liquids back to the top end of the gutter. This sytem has two advantages. First, a large number of gutters can be handled with no additional outlay other than the plumbing to pipe the liquid into each gutter. Secondly, the pump needs to run only during the flushing operation which may reduce operating costs. The disadvantage of the pump flush is that it requires a relatively high powered large capacity pump compared to a small continuous pump used to fill a siphon or tipping tank.

Storage requirements

Since the success of a reflushing gutter system depends upon a high quality flush liquid, the manure storage can be a factor in flush liquid quality. The manure must go through a solids settling facility before it reaches the liquid storage facility if low solids, high quality liquid is to be obtained in the storage pond. Settling may be done in a concrete pit adjacent to the barn or it can be accomplished by a small primary stage in the earthen

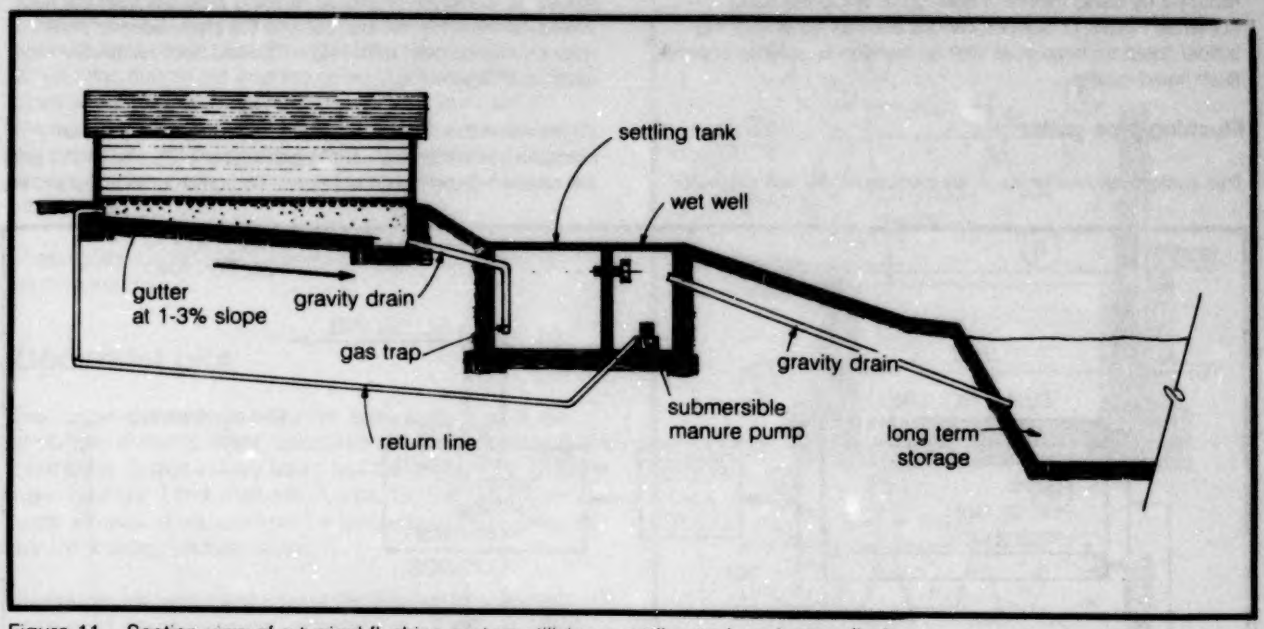


Figure 11 – Section view of a typical flushing system utilizing a settling tank and pump flush.

Discharge pipes in a flushing gutter barn. The flushing liquid is provided by a pump.

Large capacity valves may be necessary to direct flushing liquid to the manure collection areas of the barn.

storage. Mechanical separators are available on the market and are further discussed in the section on this subject. Removing solids before they get to storage also reduces solids build-up and removal problems in the liquid storage facility.

Some operators have encountered severe odor problems from recycled liquid from earthen storages particulary during the winter. This is because of anaerobic conditions that result from ice coverage on the storage pond. This condition can be

reduced by using minimum aeration to scrub the pond contents. Figure 12 outlines various alternatives employing solids/ liquid separation as well as aeration in order to improve flush liquid quality.

Flushing pipe gutter

This system is usually made by casting a 150 mm diameter asbestos, concrete or plastic flushing pipe beneath the floor with a 40 mm (1.5 in.) slat cut into the pipe. Several pipes may be laid parallel to create a "slotted floor" with very wide slats (see Figure 13).

Where more than one slot is used, a 50 mm (2 in.) slot is placed against the back of the pen wall and 25 mm (1 in.) slots are spaced 600 mm (24 in.) apart. To construct this system, the

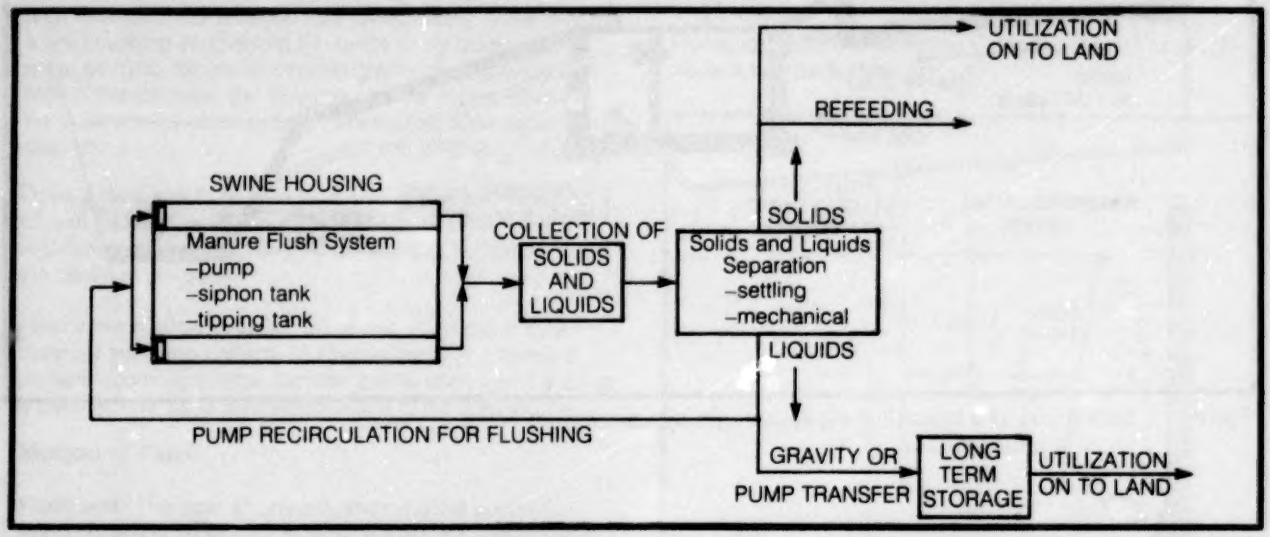


Figure 12 – Schematic showing flushing gutter options.

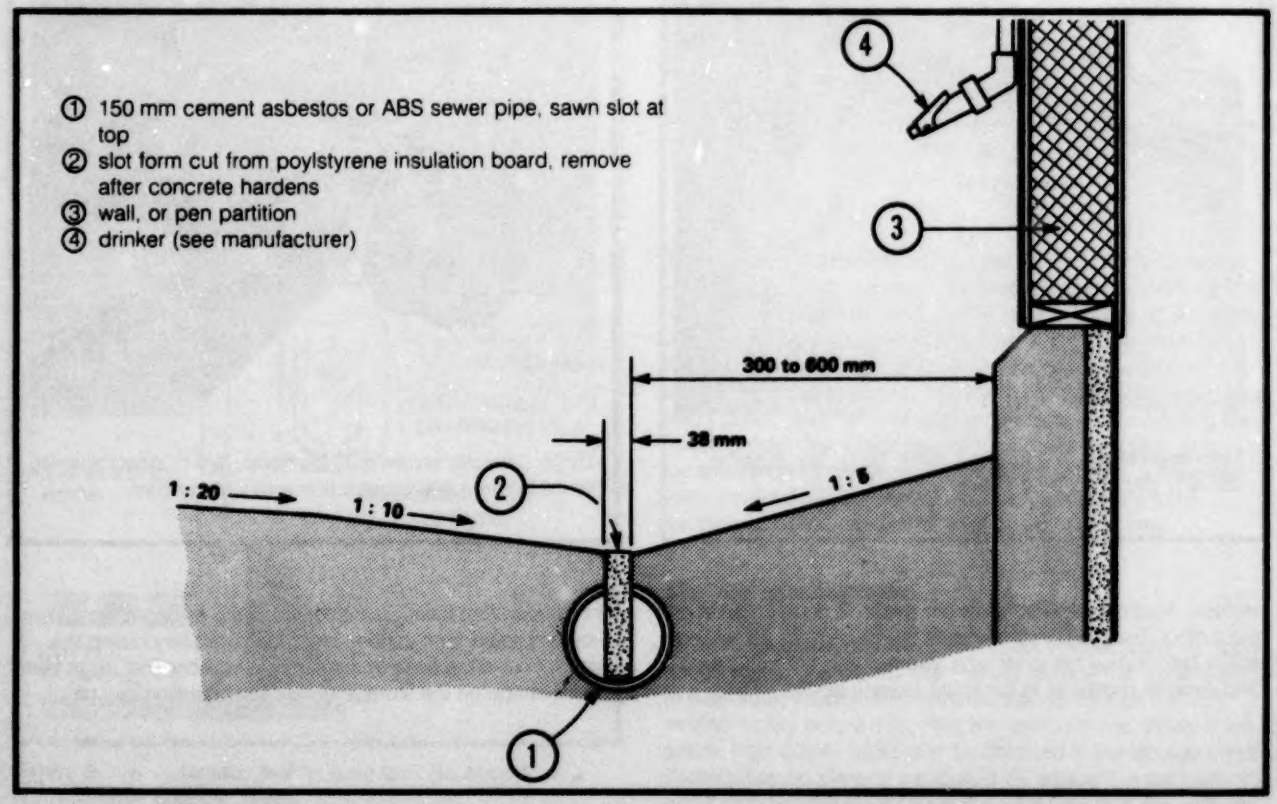

① 150 mm cement asbestos or ABS sewer pipe, sawn slot at top
② slot form cut from poylstyrene insulation board, remove after concrete hardens
③ wall, or pen partition
④ drinker (see manufacturer)
4
3
300 to 600 mm
38 mm
1 : 20
1 : 10
2
1 : 5
1

Figure 13 – Flushed slot design details. Several flushed slots may be installed to act as a partially slatted floor.

pipes are placed in position on the grade with a 0.5% slope and with slots pre-cut into the pipe. Smooth wood or polystyrene boards are inserted on edge into the slot in the pipes to form continuous openings when the concrete is placed. After the concrete sets, the boards are removed to open the slot. The pipe slope can be accommodated by varying the thickness of concrete covering the pipe or by sloping the pen floors.

These gutters need only be flushed once or twice daily to remove the manure.

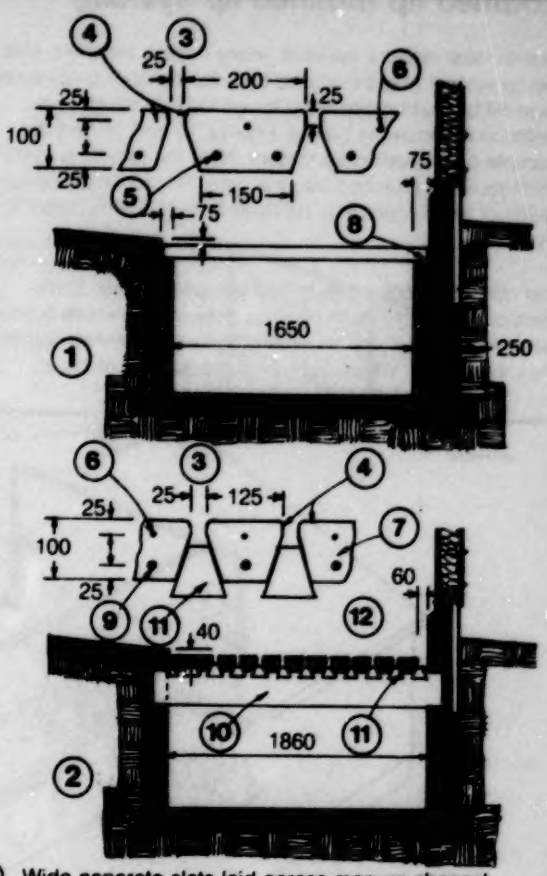
Underslat pits

Flat bottom gutters have fallen into some disfavor since the prolonged in-barn storage associated with these gutters often contributes to high in-barn odors and the release of toxic gases upon cleanout. Other methods of collection that result in more rapid removal of manure from the barn should be investigated before deciding on this method.

Where climate, siting and type of farming permit spreading manure at regular intervals, underslat pits 1.2 to 2.0 m deep may be able to provide enough in-barn storage, though not the 6 months generally recommended. Pipe cleanouts for unloading by vacuum tanker must be installed. Manure should not be expected to flow more than 4 m to a cleanout, therefore, a spacing of cleanouts should be 8 m on centre.

For complete cleanout, the sump under each cleanout pipe should be at least as deep as the diameter of the cleanout pipe and tanker suction hose. The submerged cleanout pipe acts as a gas trap, since only a small amount of manure in the sump is required to prevent the ventilation system from draining fresh air through the manure channels. It also ensures that manure is drawn from the bottom of the pit rather than just the top.

A partially slatted floor barn under construction. Note how the underslat pits are divided into compartments each with its own access pipe.



① Wide concrete slats laid across manure channel
② Narrow concrete slats laid parallel to manure channel
③ Slot widths can be suited to other sizes of pigs.
④ Smooth 'pencil' radius prevents chipped edges.
⑤ Bottom rebars, 2 of 10 M size for 1800 mm span as shown.
⑥ Top rebar prevents breakage when lifting slats.
⑦ Concrete, 35 MPa strength, maximum aggregate of 12 mm.
⑧ Ends of slats grouted in with mortar to hold uniform spacing.
⑨ Bottom rebar size 15 M for up to 1500 mm support spacing.
⑩ 38 x 235 pressure treated wood slat supports bedded in mortar into pocket 75 mm deep formed with polystyrene block, support spaced 150 mm from each end of slats up to 1800 mm long
⑪ Spacer wedges of 12 mm exterior plywood, soaked in wood preservatives, galvanized roofing nails into support beams
⑫ Wider slat at wall prevents manure buildup, reduce to 38 mm for weaner pigs.

Figure 14 – Concrete slotted floor details for swine pens. With this support method, slats can be laid parallel to the walls for better self-cleaning.

Modified lip (flushed lip system)

As with most manure systems, many design variations exist. The lip system may be altered from the description given on page 10 by making provision for periodic flushing. (e.g., gestation or farrowing barns). Figures 15 and 16 give an example of a modified lip system. Note the recycling system which must be plumbed into the barn. Recirculated manure liquids or fresh water may be used to flush the modified lip system.

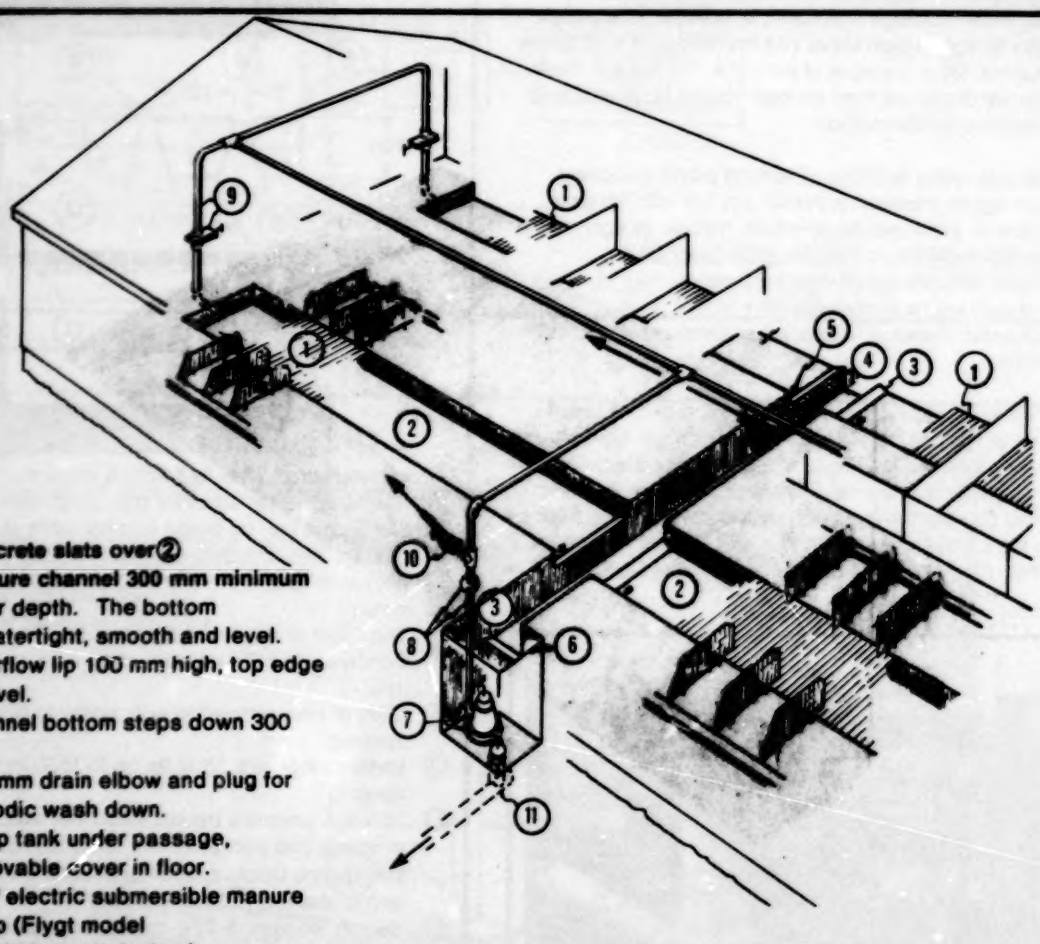
How often the modified lip is flushed varies widely. Some operators flush only upon need i.e. only when manure builds up under the slats. Others systematically flush every half day to every three days. Where such frequent flushing of the lip system is planned, the lip itself may be reduced to 50 mm (2 in.) and the gutter depth may be reduced since the manure is moved along the gutter by the flush water rather than by gravity.

Advantages:

- manure removal assured
- rapid removal from gutter, therefore less odor
- gutter may be slightly shallower.

Disadvantages:

- added cost owing to pump and recycling system
- added mechanization and maintenance requirements



① **Concrete slats over ②**
② **Manure channel 300 mm minimum clear depth. The bottom is watertight, smooth and level.**
③ **Overflow lip 100 mm high, top edge is level.**
④ **Channel bottom steps down 300 mm.**
⑤ **100 mm drain elbow and plug for periodic wash down.**
⑥ **Sump tank under passage, removable cover in floor.**
⑦ **2 HP electric submersible manure pump (Flygt model FS 3082, or equivalent).**
⑧ **100 mm pipe riser with quick coupler to disconnect when lifting pump ⑦ for service.**
⑨ **100 mm PVC recirculation piping, gate valves, fittings solvent welded.**
⑩ **Valve and pipe to above ground manure storage, drain back to ⑧ after pumping.**
⑪ **Pail valve to 200 mm sewer pipe sloped at 1:100 to underground storage.**

Figure 15 – Continuous flow (lip) manure system with pump-flushing system added (adapted to CPS plan 3236, Breeding/Gestation unit).

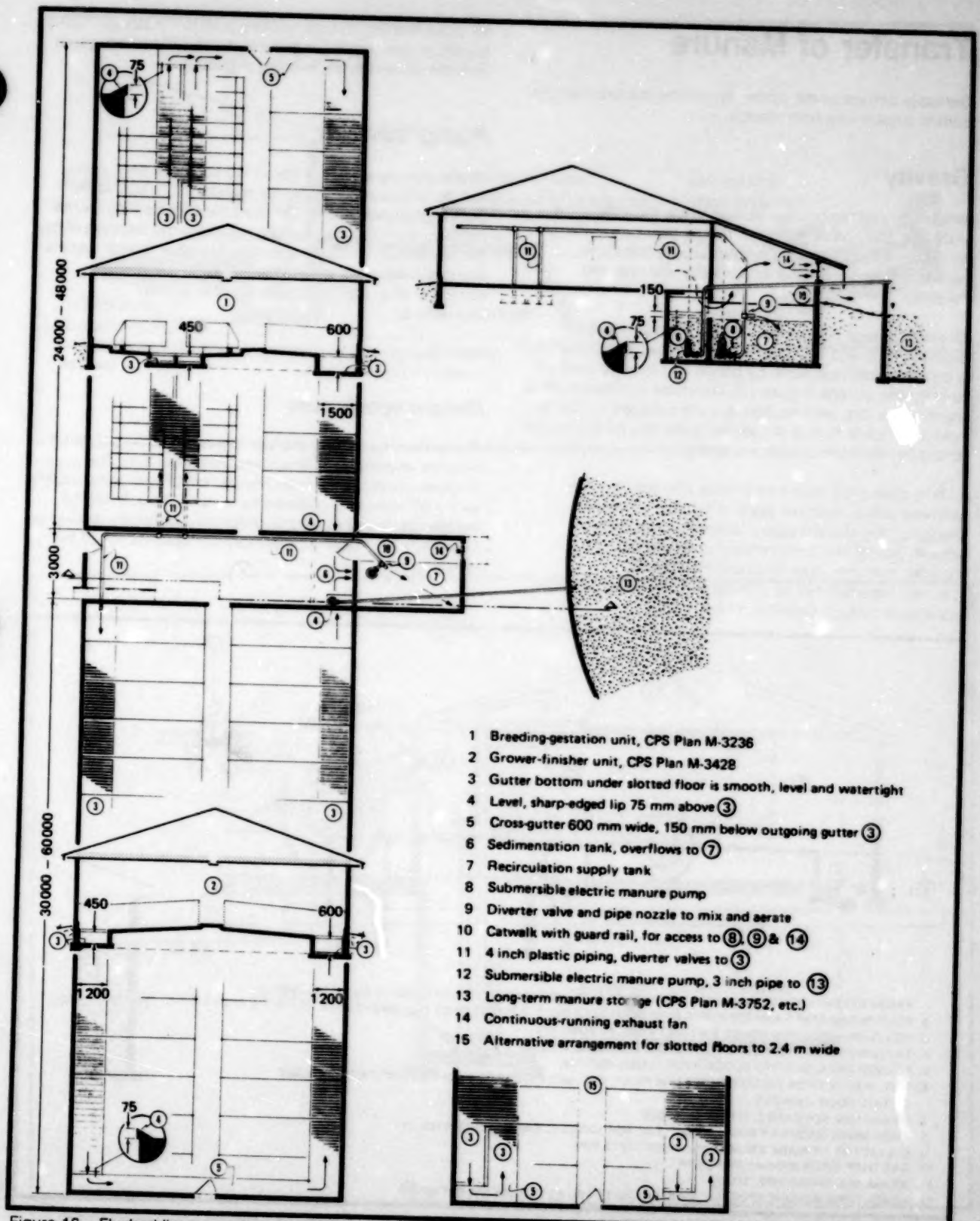

75
450
600
1500
3000
24000 – 48000
30000 – 60000
1200
1200
150
75
1 Breeding-gestation unit, CPS Plan M-3236
2 Grower-finisher unit, CPS Plan M-3428
3 Gutter bottom under slotted floor is smooth, level and watertight
4 Level, sharp-edged lip 75 mm above (3)
5 Cross-gutter 600 mm wide, 150 mm below outgoing gutter (3)
6 Sedimentation tank, overflows to (7)
7 Recirculation supply tank
8 Submersible electric manure pump
9 Diverter valve and pipe nozzle to mix and aerate
10 Catwalk with guard rail, for access to (8), (9) & (14)
11 4 inch plastic piping, diverter valves to (3)
12 Submersible electric manure pump, 3 inch pipe to (13)
13 Long-term manure storage (CPS Plan M-3752, etc.)
14 Continuous-running exhaust fan
15 Alternative arrangement for slotted floors to 2.4 m wide

Figure 16 – Flushed lip system for removing liquid swine manure from long gutters under slotted floors, with improved 'hairpin' gutter layout.

Transfer of Manure

Generally defined as the system for moving manure from the barn to outside long term storage.

Gravity

Where site conditions allow storage below the level of the collection area, collected liquid manure may be transferred by gravity through a piping system. Gravity transfer is recommended because of its simplicity, low cost and reliability.

Gravity drainage is often used with pump transfer. For example, stop and flow sytems in the barns may discharge to a common collection sump by gravity and then be pumped to long term storage (Figure 17). Whenever a collection pit is used before long term storage, provide sufficient volume to hold a complete flush of the largest gutter in the housing unit to ensure rapid and complete draining.

Gravity drain lines should be at least 200 mm (8 in.) in diameter with a minimum slope of 1:100 to minimize plugging. Any durable pipe material that has relatively smooth interior and is economical is satisfactory. This includes concrete, clay, steel and PVC plastic.
It is very important that all parts of the drain must be accessible through cleanouts or wet wells.

All pipes leading from the housing area to the storage facility should be gas trapped to prevent the flow of noxious gases from the storage to the building (Figure 2).

Pump transfer

Where manure storage is above the collection area, pump transfer is required to move the manure to storage. Many pump types and designs are available commercially for this purpose. Pumping hog manure is a challenge because of its content of hair, afterbirth, shavings and other foreign objects. The basic design of pump transfer must allow for easy access of all pumps and pipes to allow for easy maintenance.

Pump transfer can be undertaken by the following pump types:

Chopper agitator pump

The primary function of this pump is rapid loading of tanker wagons. Manure transfer is a secondary function. The chopper agitator is an open impeller centrifugal pump usually with a 90° drive and powered by a tractor PTO. It may be installed permanently and powered by a stationary electric or fueled engine. Figure 19 illustrates the basic design of this type of pump.

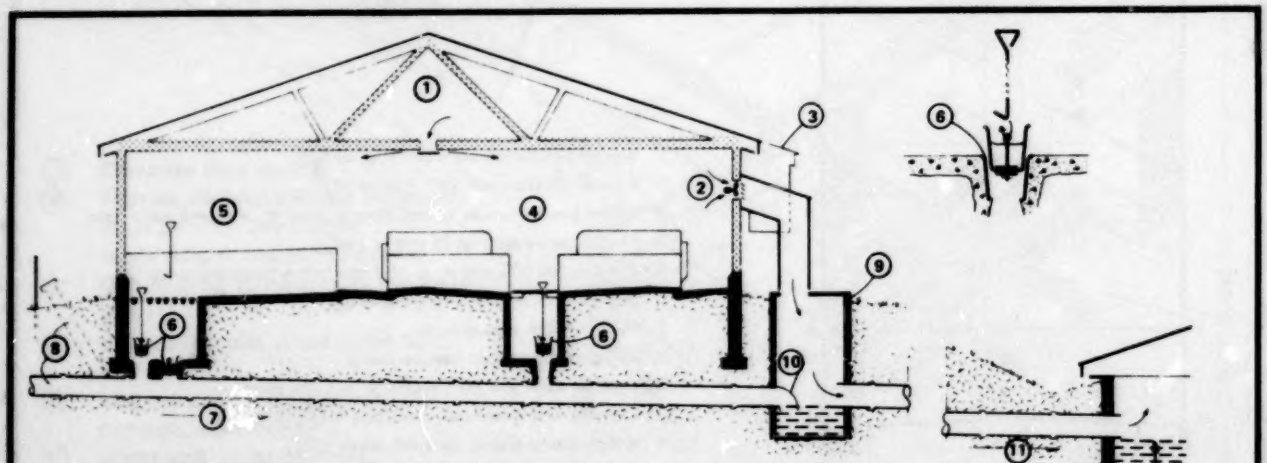

1. FRESH AIR ENTERS VIA INSULATED ATTIC DUCT AND ADJUSTABLE CEILING CENTER INLET (PLAN 9711)
2. CONTINUOUS STEP 1 FAN EXHAUSTS INTO INSULATED DUCT, REMOVE DUCT FOR SUMMER
3. WEATHER–HOOD FOR OTHER EXHAUST FANS, BEYOND (2)
4. FARROWING AREA, GUTTERS SCRAPED TO SUMP BOX
5. WEANER AREA, SLOTTED FLOOR OVER FLUSH–GUTTER
6. PAIL–VALVE FROM 2 MATCHED PLASTIC PAILS, EYE–BOLT & LARGE WASHERS, CONCRETE BALLAST, LIFTING HOOK–HANDLE
7. 200mm MIN. SEWER PIPE, 1:100 MIN. SLOPE
8. FROM SWINE GROWER/FINISHER UNIT, ETC. (OR 100mm CLEANOUT PIPE WITH CAP
9. COLLECTOR PIT MADE FROM 1200mm CONCRETE PIPE
10. GAS TRAP, FROM 200mm PIPE ELBOW
11. 300mm MIN. SEWER PIPE TO (12)
12. LONG–TERM MANURE STORAGE, MAX. LIQUID LEVEL AT OUTLET INVERT OF (11)

Figure 17 – Typical liquid manure system with gravity flow to remote long term storage and exhaust ventilation protection.

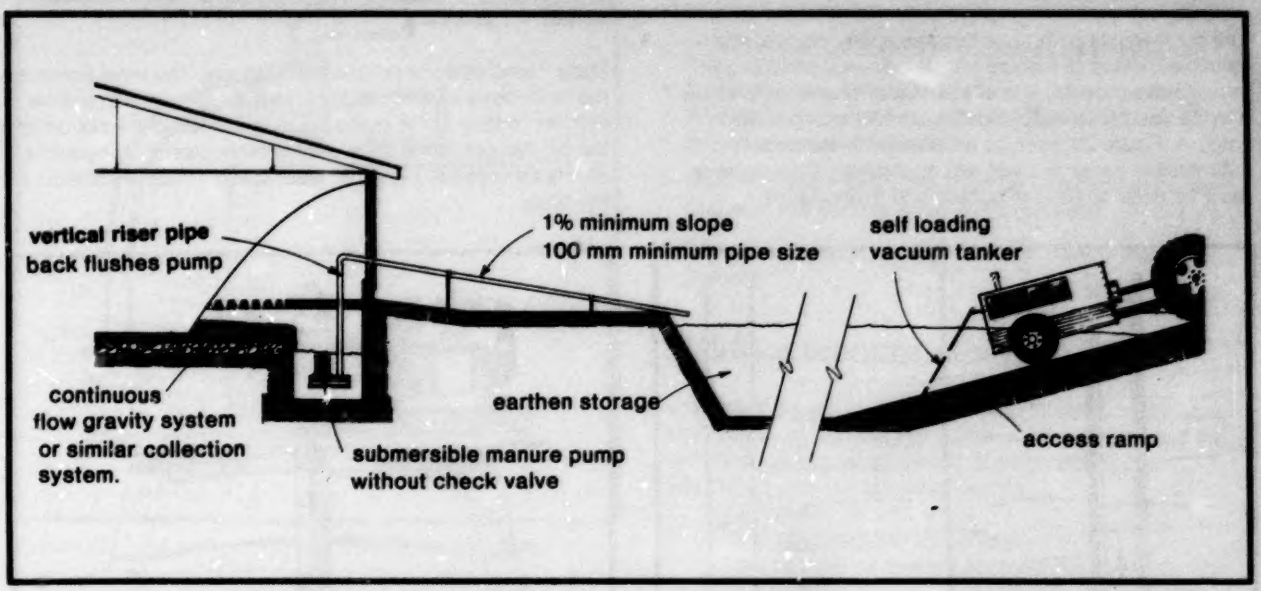


Figure 18 – A typical above-ground pump transfer system.

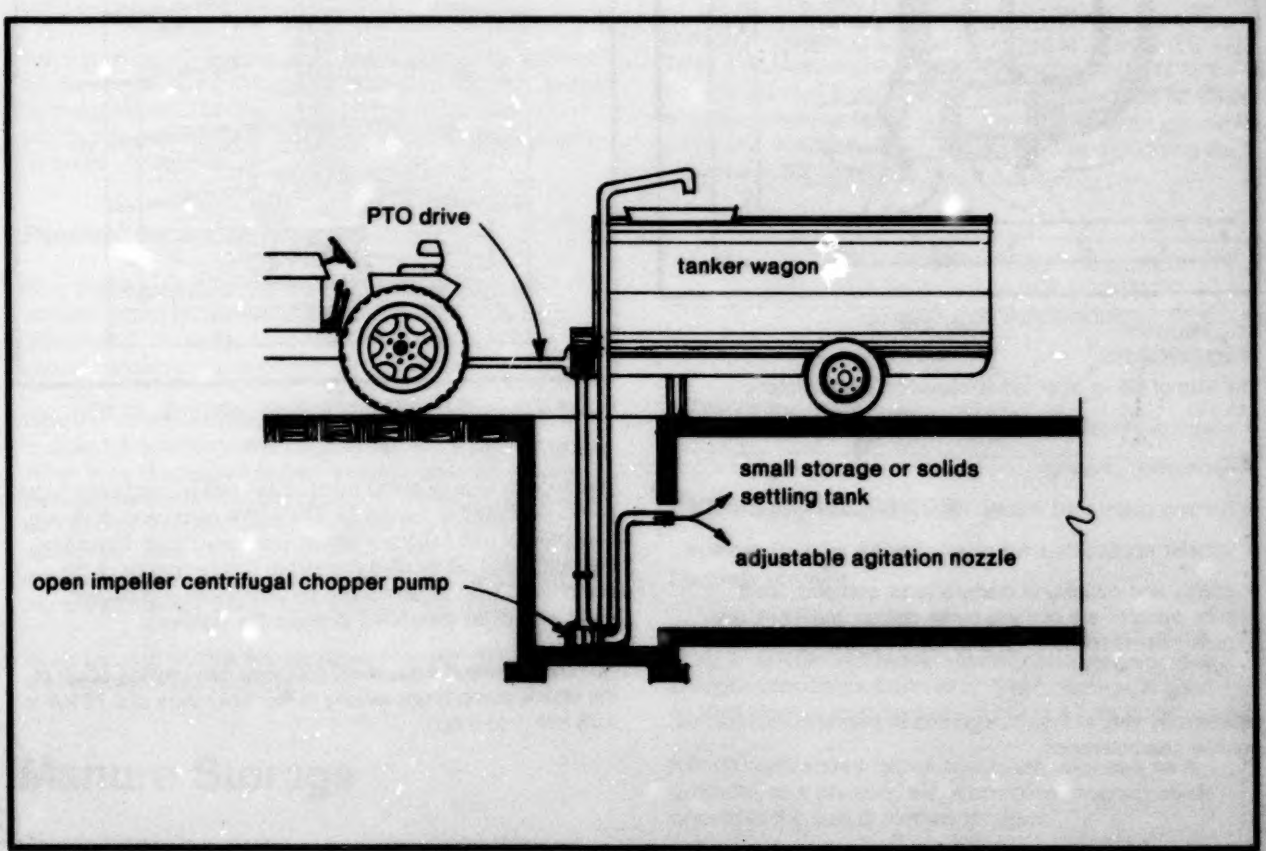


Figure 19 – PTO driven chopper pit pump. Ideal for agitating and transferring manure from small storages.

Submersible pump

The submersible pump has become a very popular and valuable method of manure transfer. Several commercial makes have proven to be effective and reliable units which may be used for transfer, flushing or for loading tanker wagons. Figure 20 gives as an example a sketch of a submersible pump in a wet well application. Consideration must be given to ease of access and maintenance.

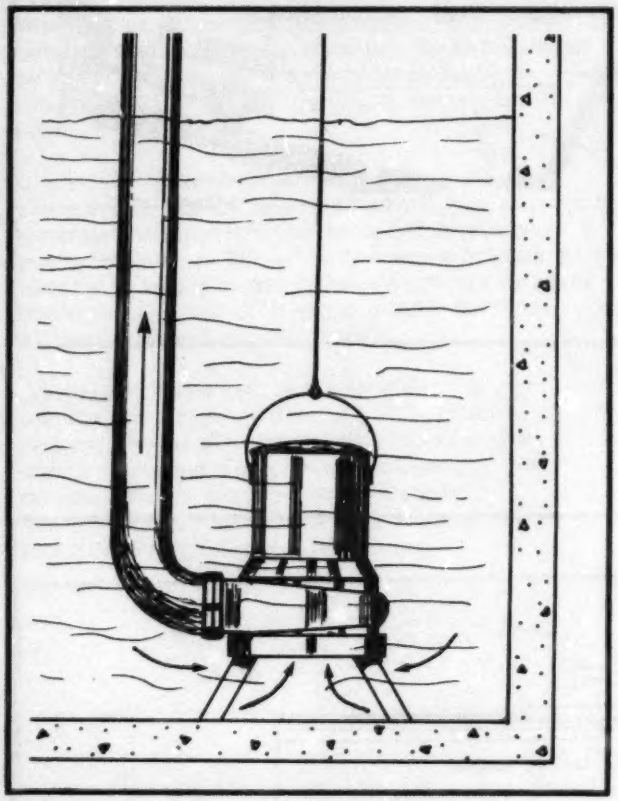


Figure 20 – Submersible manure pump.

The size of pump selected is based on these factors:

- electrical limitation
- application of pump
- flushing gutters will dictate volume requirements
- transfer applications are usually flexible so don't oversize
- quality and quantity of manure to be pumped. Most submersibles are of trash pump design, therefore, will pass coarse solids. e.g., a 3 hp pump will usually pass 50 mm (2 in.) solids.

Makes may vary in their design and in their specific head vs. volume characteristics.

Wet well centrifugal transfer pumps (above liquid drive)

Many pump designs fall into this category. The most common pump involves a drive usually above the pit roof with a drive shaft extending to the pump housing located at the bottom of the pit. Access to the drive unit, whether electric or hydraulic, is very convenient. Figure 21 illustrates a typical installation of this type.

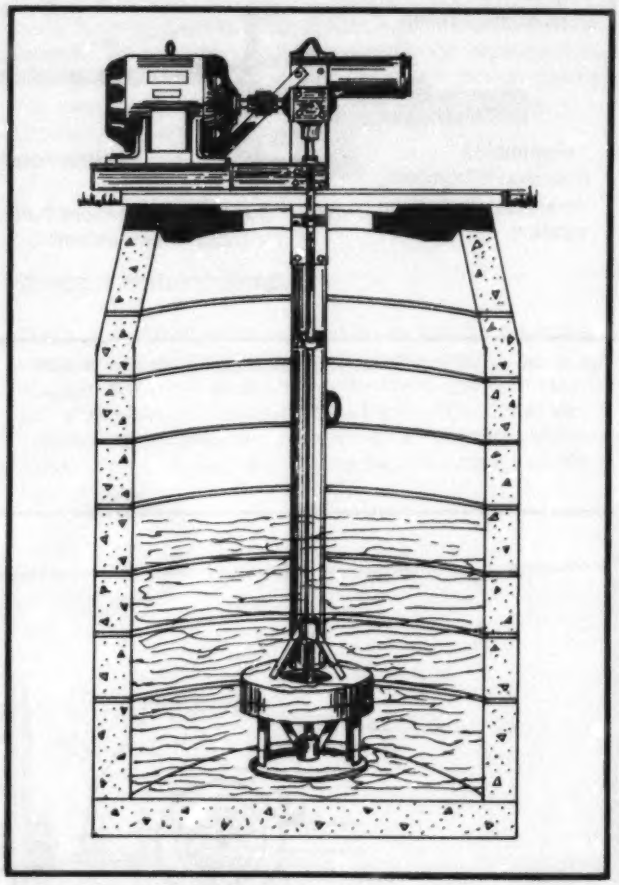


Figure 21 – Wet well transfer pump (above liquid level drive).

The second type of sump pump is the self-priming centrifugal pump illustrated in Figure 22. The entire pump and drive are one integral unit making maintenance very convenient since the pump can be located somewhat independently of the sump itself. Loss of prime can be a problem and suction head should be minimized to avoid this problem.

Domestic sewage equipment suppliers can provide either of the above pump types usually in the size range of 0.75 kW to 3.75 kW (1 to 5 hp).

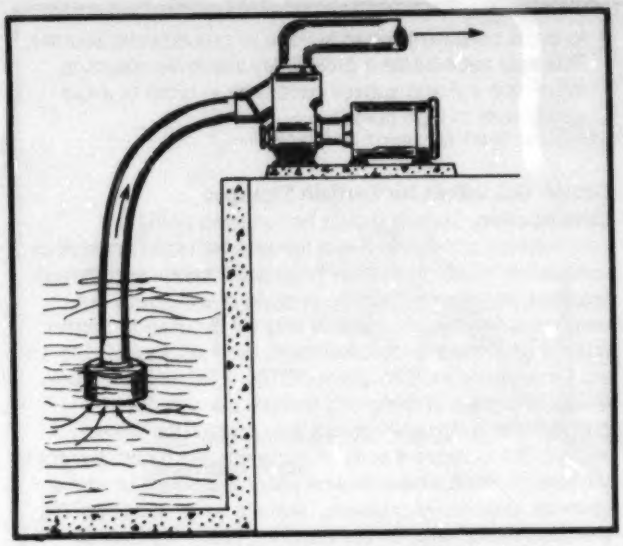


Figure 22 – A self-priming wet well centrifugal pump.

The basic requirement of transfer pumps is low head and high volume. They must be able to handle solids at least 40 mm in diameter without clogging. Bearing design seems to be quite critical when pumping hog manure. Buyers are encouraged to investigate whether or not the particular pump can be used with hog manure before purchasing it.

Many of the larger transfer pumps can be used as agitators for manure storages. Chopper pumps are particularly suited for this purpose. They have an agitation radius of about 10 m (30 ft). The smaller sump type pumps may only be suitable for small holding pits.

Plumbing for transfer systems

Pipe diameters for pump transfer depend upon solids content, pump capacity and length of transfer line. Pipe diameters in the range of 75 mm to 150 mm (3 to 6 in.) should handle any possible transfer situation.

Where lines are exposed to freezing, they should be sloped to drain back to the pump sump or out to the storage facility. When lines are below freezing, a check valve will prevent storage manure from draining back to the pump. Care should be taken to not install the check valve in a vertical pipe as solids may settle on the check valve causing it to plug. Fresh water should be used to flush the lines after transferring manure to prevent solids from settling in the lines.

Many types of pumps are available, however, gravity transfer is preferred where possible.

Manure Storage

Manure storage is desirable in most manure management systems to eliminate the daily chore of disposal and also to allow applications of manure to land at optimum times for utilization by crops. Manure storages should be designed to:

- Provide sufficient volume to minimize winter spreading.
- Provide sufficient storage to allow flexibility in utilizing it on land disposal. Timely spreading of manure on land maximizes nutrient benefits.
- Manure storage structures must be watertight to prevent seepage into surface water or groundwater.
- Storage sites must be accessible for ease of manure removal.

Sizing a manure storage

The size of a manure storage facility depends on the type and number of animals, the length of storage time and the volume of dilution water added. Storage size can be determined with the following formula:

VS = (Na x Vm x T) + Vw

VS = volume of storage in litres
Na = number of animals confined during the storage period
Vm = volume of manure produced in litres per animal per day (see Table 2)
T = storage time desired in days
Vw = volume of dilution water added to liquid manure storages in litres

Storage requirements can be calculated in different ways. Table 4 may be helpful in planning new hog facilities as the storage volumes are calculated on a per sow basis for either a farrow-weaner or farrow-finish operation. Storage volume for a 150 sow operation could be calculated by multiplying the volume per 100 sows by 1.5.

TABLE 4. EARTHEN LAGOON STORAGE REQUIREMENTS FOR HOGS BASED ON A PER SOW BASIS.

	VOLUME/ SOW/DAY		VOLUME/ 100 SOWS/DAY	
	L	(ft^3)	m^3	(ft^3)
Farrow-weaner	20	(0.71)	2.0	(71.4)
Farrow-finish	78	(2.8)	7.8	(278)

Types of storages

Earthen storage

In areas of low groundwater pollution hazard and where siting is suitable with respect to neighbors, open earthen storages provide inexpensive long-term storage. A good earthen storage must be more than just a hole in the ground.

Alberta Agriculture regional agriculture engineers have available, as a planning aid, a computer program which calculates the size of earthen storages.

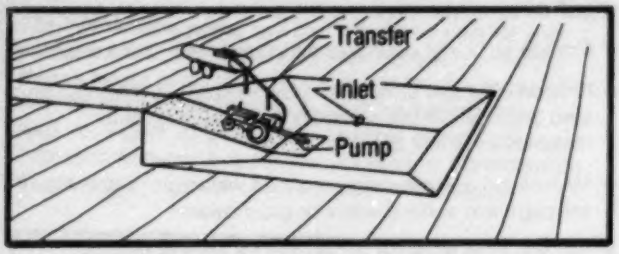


Figure 23 – Earthen storage with ramp access.

Siting of Earthen Storage

Essentially, all livestock storages in Alberta operate anaerobically, i.e., undergo odor producing biological decomposition. Odor is, therefore, a very important consideration when designing and locating an earthen storage. An earthen storage should be located:

- far enough away from any residential area to avoid creating a nuisance. The Minimum Distance Separation siting criteria should be met. This method of siting assessment is outlined in the guidelines found in the Code of Practice.
- on the leeward side of the farm house
- in an area with suitable space for expansion
- to control surface drainage to the lagoon from adjacent areas
- to avoid contamination of surface or groundwater sources. This may necessitate a preliminary site investigation to determine soil and subsoil conditions in order to avoid sandy soils of high porosity.

Design Guidelines for Earthen Storages

Construction: Topsoil should be removed from the embankment areas and the dikes constructed of impervious compacted material. If highly permeable sands and gravels are encountered, an impervious lining of clay, butyl film, concrete or equivalent material may be required to protect against groundwater contamination. Side slopes of 2:1 to 4:1 are recommended. CPS plans M2701, 2702 and 2704 are available to help in designing manure storage. Berm construction is designed to not only contain the stored manure but to prevent entry of surface water runoff. Except in the rare situation where dilution water is desired, or where sprinkler irrigation is practised, surface water increases the storage volume requirements and increases the cost of disposal.

Inlets: Lagoon inlets should be located so that solids will be distributed over the lagoon and not allowed to accumulate near the edge. Both above-surface and below-surface inlets may be used depending upon the topography and elevation differences between the barn and the lagoon site. Below-surface inlets are preferred as they produce less surface disturbance, odor and nutrient loss (see Figure 25).

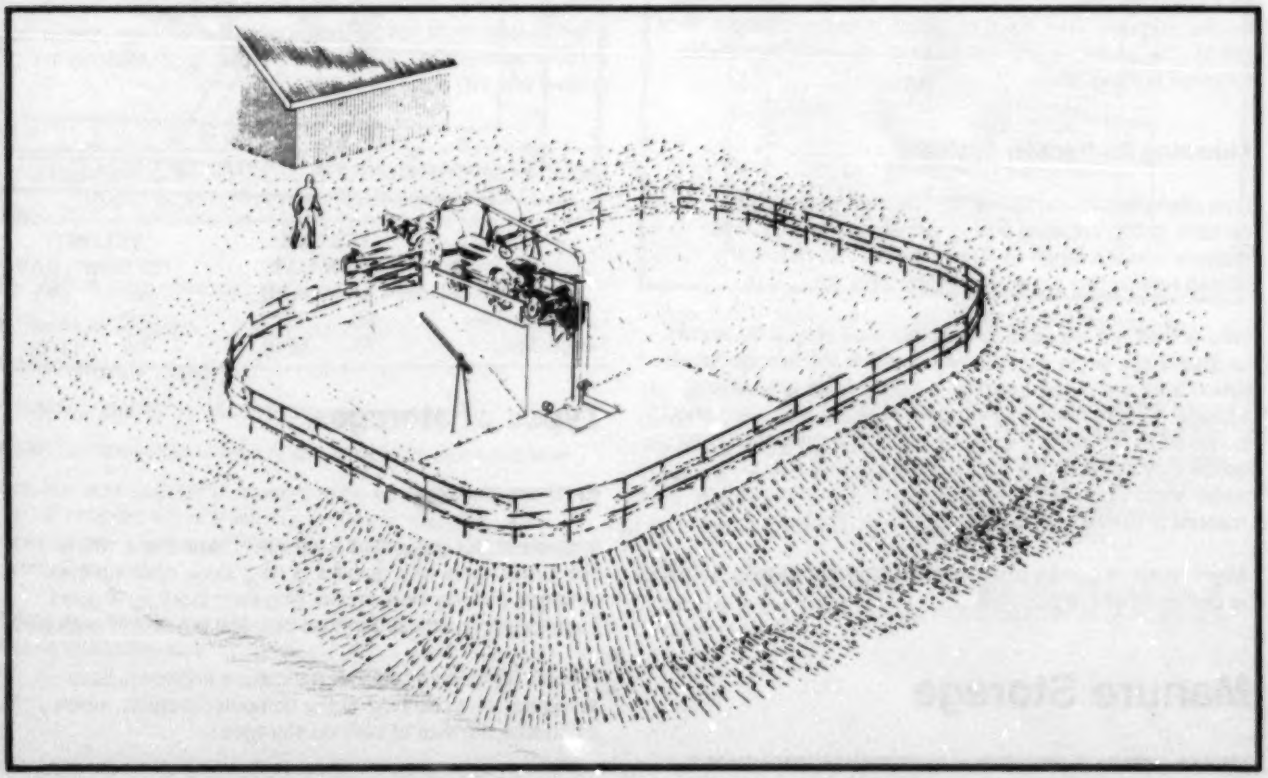
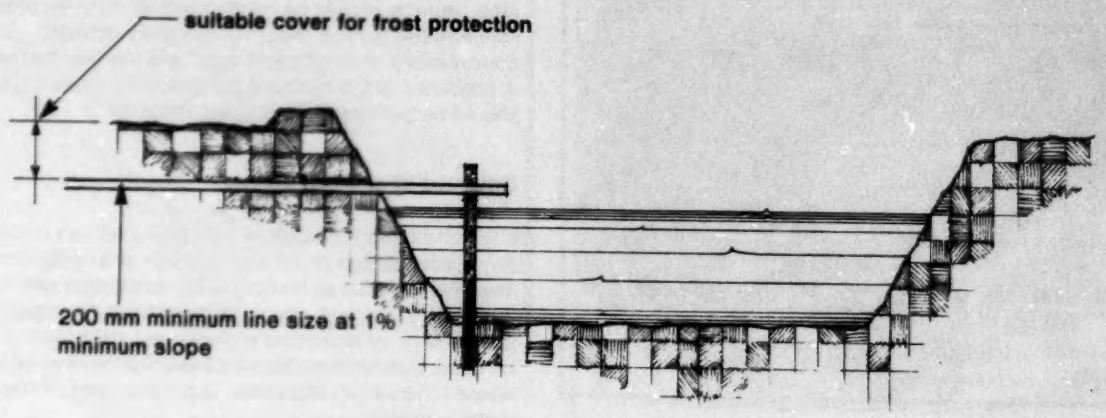
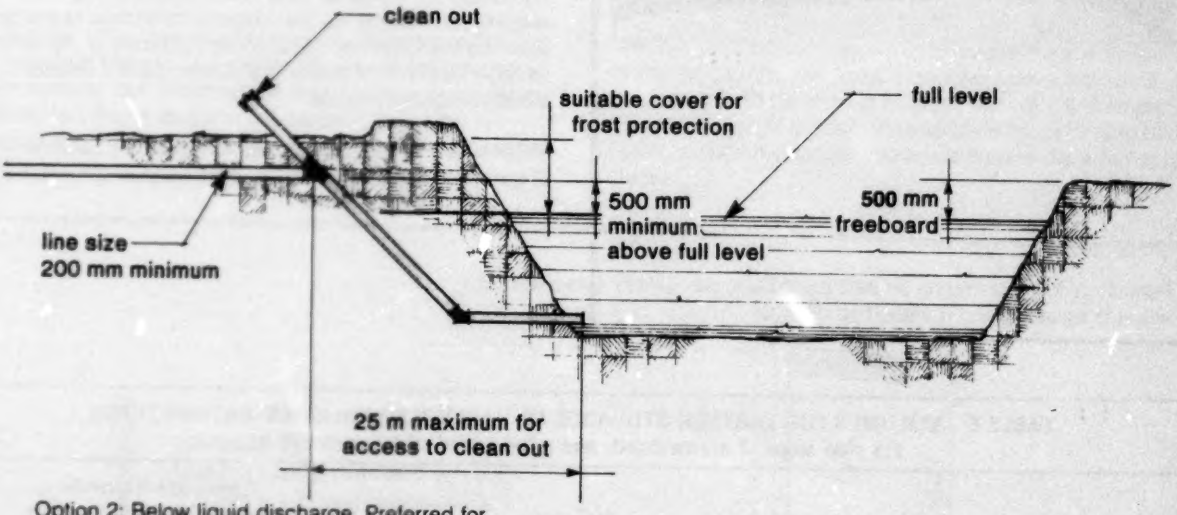


Figure 24 – Earthen storage with pumping dock (CPS 2702).



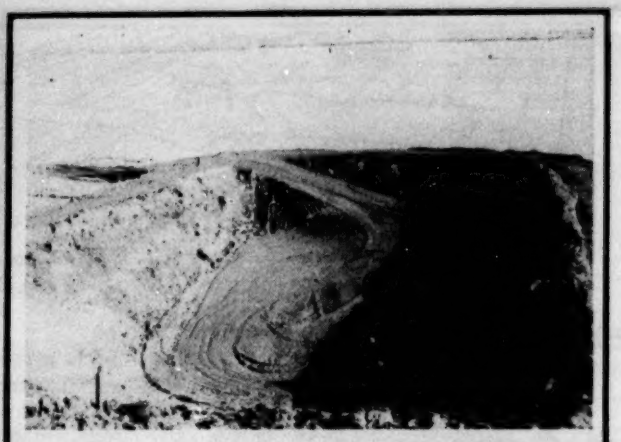
Option 1: Above liquid discharge. Subject to ice build-up in storage, but most reliable. Creates more storage disturbance, therefore, more odor and nutrient loss.


clean out
suitable cover for frost protection
full level
500 mm minimum above full level
500 mm freeboard
line size 200 mm minimum
25 m maximum for access to clean out

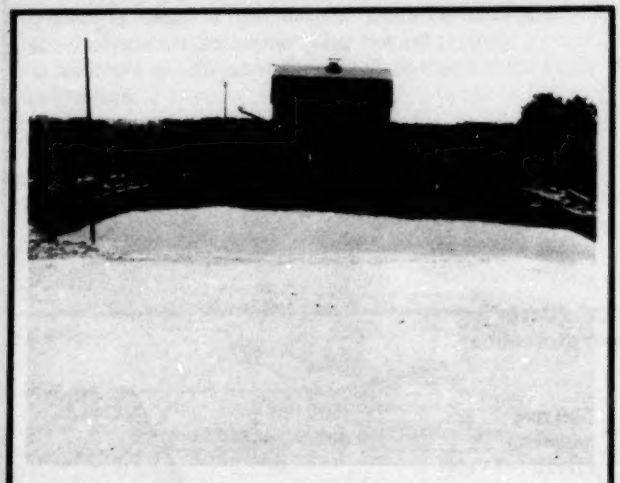
Option 2: Below liquid discharge. Preferred for lagoon management.

Figure 25 – Two methods of entering earthen storages with gravity drainage lines.

Access: Access to the lagoon should be provided for a pump for the regular removal of the lagoon contents. Recommended methods for providing access are either a concrete ramp or a pumping dock. Lagoons storing semi-solid or solid manure should have the entire bottom covered with concrete to facilitate entry of equipment for manure removal. The top of the berms should be at least 3 m (10 ft) wide to allow equipment to move around the lagoon. Slopes on the outside of the lagoon embankments should be low enough to allow mowing.



An earthen storage under construction. Note the entry ramp to facilitate manure removal.



Partially or fully concreting an earthen storage can greatly assist in agitating and transporting manure.

Shape: Lagoons may be square, rectangular, circular or elliptical to allow good mixing of the lagoon contents. The shape is largely determined by the local topography. Since odors and nutrient losses are directly related to the surface area, lagoons should be constructed as deep as possible to minimize the surface area. Table 5 gives different combinations of length, and width and the resultant volume. A freeboard of 0.5 m above the maximum operating level should be provided for unexpected rainfall.

Covered in-ground storage

In-ground tanks, because of their high cost, are limited to short-term storage (3 months) and wet well applications. They may also be used as holding tanks associated with manure treatment processes where solids removal for refeeding, high rate aeration or anaerobic digestion are employed. A concrete tank is also suitable as a solids settling facility where solids-liquid separation is required (e.g., flushing gutter system).

Gravity or pump transfer can be used for an in-ground storage facility. Pipes or openings to the tank from the barn should be plugged or a gas trap installed to prevent manure gases from returning into the building.

Provision must be made to handle the anticipated agitation equipment for solids removal. Check the opening clearance required for various pumps. Location of access openings should allow complete agitation and cleanout of the entire storage facility. Remember that pumps have a limited effective agitation radius.

Either round or rectangular structures can be considered. Engineering advice should be obtained prior to construction

TABLE 5. VOLUMES FOR EARTHEN STORAGES OF VARYING DIMENSIONS. ASSUMPTIONS 2:1 side slope, 3 metre depth and a freeboard of 0.5 metre (2 ft).

Storage Size		Volume Cubic Metres		Adequate 6 month Storage for the following Farrow-Finish Operation
m x m	ft x ft	m^3	(ft^3)	
15 x 15	50 x 50	175	(6173)	12 sows
15 x 23	50 x 75	330	(11673)	24
15 x 30	50 x 100	486	(17173)	35
23 x 23	75 x 75	663	(23423)	48
23 x 30	75 x 100	996	(35173)	70
30 x 30	100 x 100	1505	(53173)	110
23 x 46	75 x 150	1661	(58673)	120
30 x 60	100 x 200	3544	(125173)	250
46 x 46	150 x 150	4252	(150173)	300
46 x 90	150 x 300	9434	(333173)	650
60 x 60	200 x 200	8414	(297173)	600

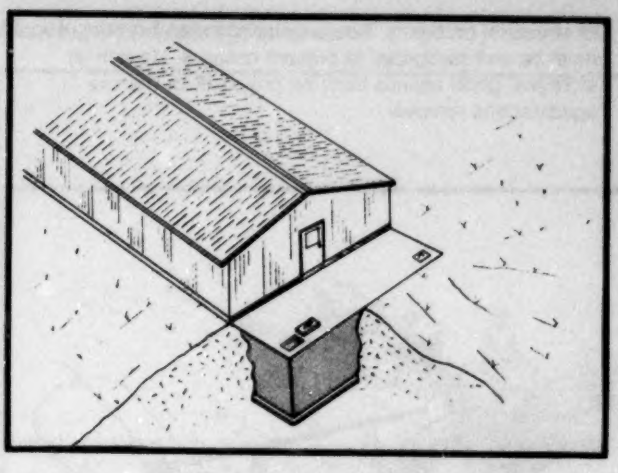
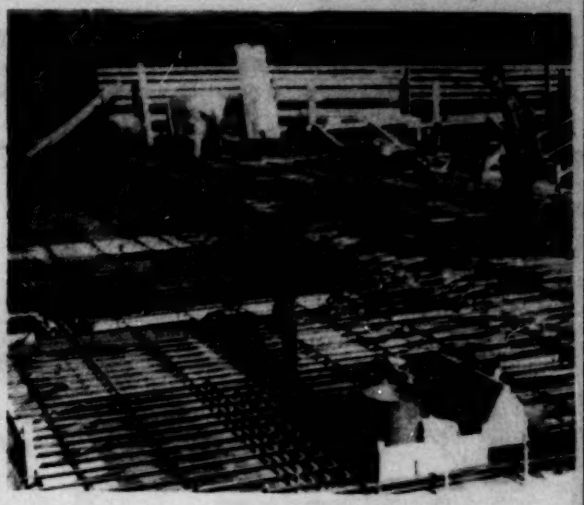


Figure 26 – Covered concrete in-ground storage.



A fully contained concrete storage is expensive because of the structural requirements. This type of storage is limited to short term applications.

to prevent a costly and hazardous structural collapse. Figure 27 typifies standard structural details for a covered rectangular in-ground storage. The roof should be constructed to handle the dead and live loads applied to it as well as to brace the walls against inward collapse. Manure and manure gases are corrosive, therefore, high quality concrete (30 MPa) with air entrained and adequate reinforcing is recommended.

High water table sites should be avoided when considering an in-ground storage. It is practically impossible to build a below-ground tank which will be impervious to groundwater. A totally watertight structure will probably fail owing to upward and inward hydrostatic pressure, or it would tend to float out of the ground.

The floor level should, therefore, be above the water table. If, on rare occasions, the water table rises above the tank floor, seepage should be allowed to enter the tank if it is empty. Outward seepage of liquid manure does not appear to be a problem since the suspended solids tend to block the small cracks.

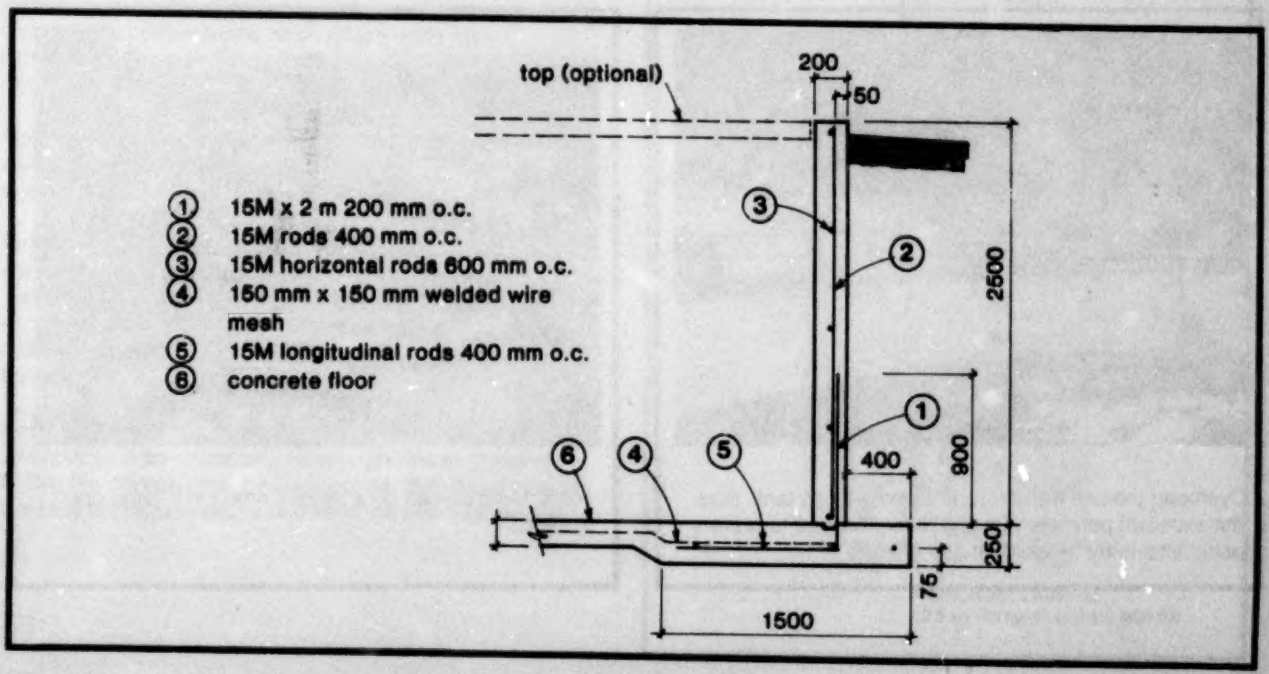


Figure 27 – Design details for an in-ground concrete manure storage tank.

Open in-ground storages

Open storages are cheaper than covered storages since the roof system represents 30-40% of the cost. A circular design such as CPS 3752 is a practical plan with a minimum number of structural problems. Rectangular pits are suitable but walls must be well reinforced to prevent collapse. As with all storages, good access must be provided for manure agitation and removal.

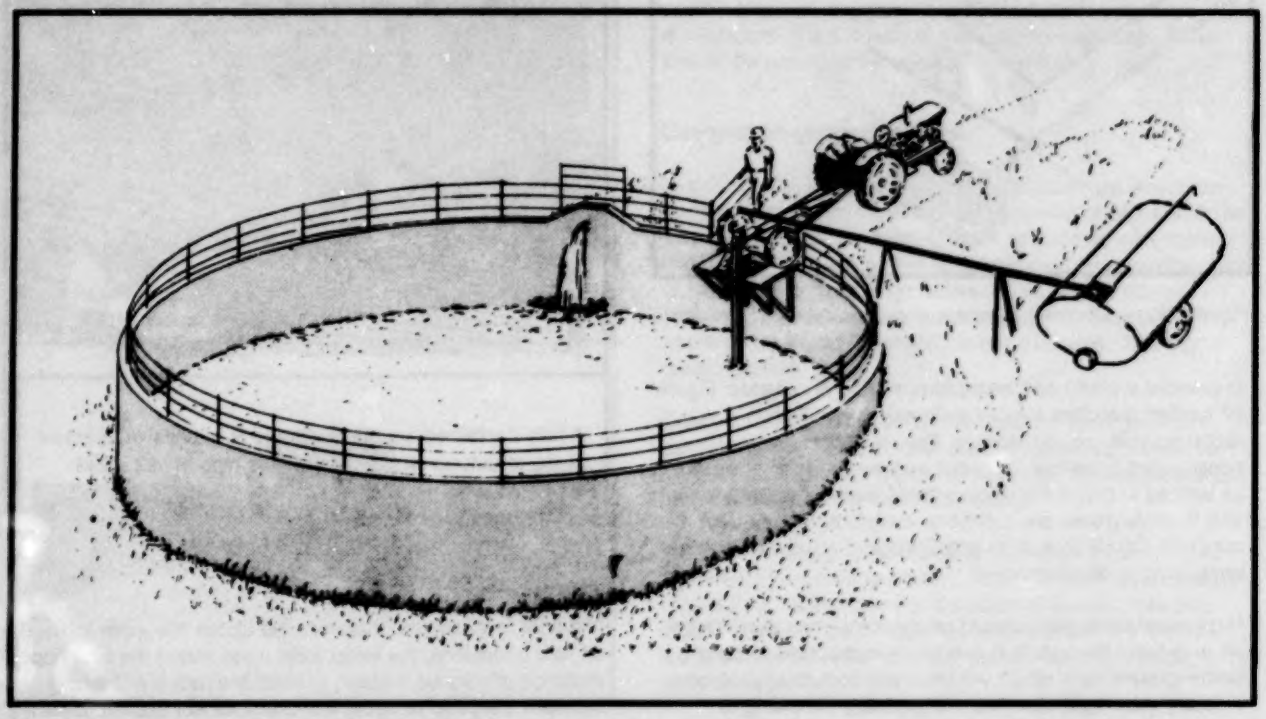
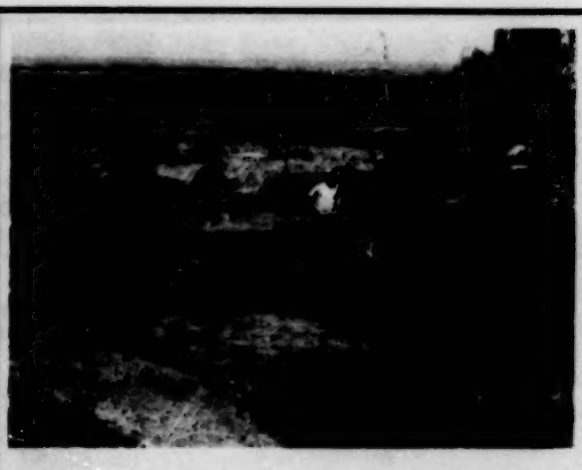


Figure 28 – Open in-ground storage (CPS M3752).

Overhead manure transfer to an open storage tank. Note the excellent perimeter fencing recommended to prevent accidental entry by children and animals.



Solids build up can be a serious problem in large open storages.

Above-ground storages

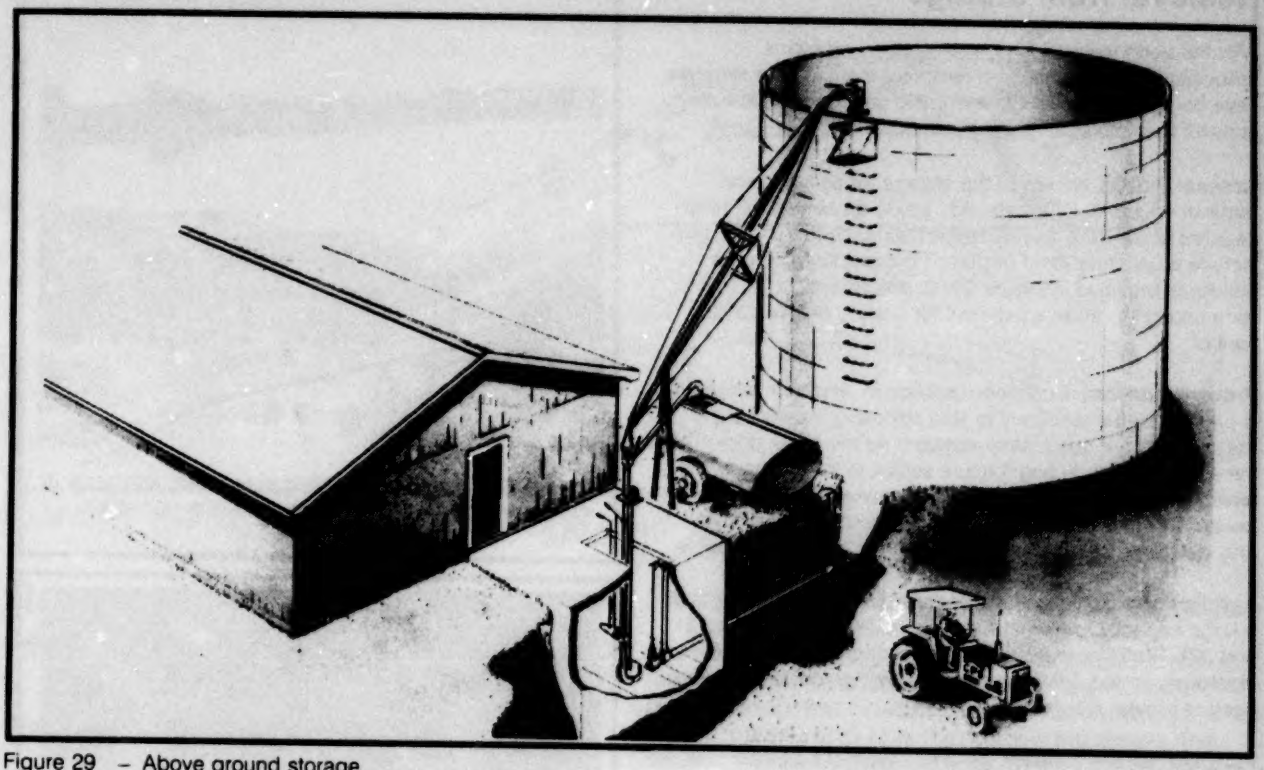


Figure 29 – Above ground storage.

Most upright silo companies sell structures suitable for manure storage. Owing to the high cost per unit stored, upright storage is not recommended for storing diluted manure such as runoff or washwater. Above ground storages should be considered only when a high water table, extremely permeable soil or fissured rock make below-ground storage impossible.

Such tanks may be constructed of reinforced monolithic concrete or steel. This type of storage can be filled by the many types of transfer pumps or by direct loading.

Proper agitation of upright storages has been a problem so care must be taken not to add an excessive amount of dry matter; the selection of proper agitation equipment is also important (see Figure 30). Precautions must be taken to prevent accidental discharge of the manure back into the barn.

Freezing in upright storages has not been a problem as long as capacity is adequate to give enough time for thawing before the storage must be pumped out. With liquid manure, the salts and suspended solids keep the mass semi-plastic.

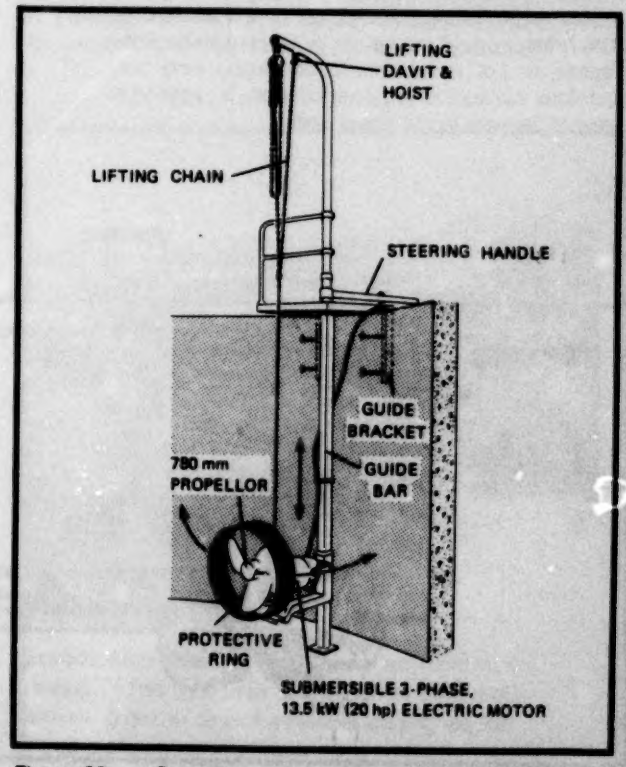


Figure 30 – Over-the-wall mounted propellor-type mixer (courtesy Flygt AB, Sweden).

Removal from storage

With the trend towards long term storage, problems associated with agitation and removing manure from storages have become common. Several basic principles for effective removal from storage should be considered.

Access: Provide access to the storage for agitation and removal equipment. This should include an all-weather road capable of handling heavily loaded equipment. It should also include a concrete ramp or pumping dock. Note how the access is provided in Figure 23. Berms should be wide enough to allow equipment for hauling and weed control.

Proper Agitation: A common problem in long-term storages is caused by the tendency to start removing liquids before the contents are adequately agitated. As the major portion of the solids fraction in hog manure settles to the bottom of the storage, the total amount there is often underestimated because of the liquid layer over top. Premature withdrawal only dewaters the solids, making further cleanout impossible.

Agitation of large volume storages requires lots of power and a large capacity low pressure, high volume pump (Figure 31 and 32). The large mass of material in the lagoon must be vigorously stirred. Effective agitation by high pressure pumps has not proven satisfactory.

Pumping manure is heavy, continous work. To be safe, tractors used to power agitator pumps should be oversized when operated continuously. For example, a lagoon pump requiring 100 hp should be driven by a power unit having 30% greater power output—in this case 130 hp. Farm tractors are not power rated for continuous peak duty, therefore, the additional power capacity is required to prevent damage to the power unit.

Any well managed manure storage requires high capacity agitation equipment to dislodge and break up settled solids.

A propellor agitator is a simple but effective method of agitating open storages. Note the long reach hitch which allows access to the storage contents.

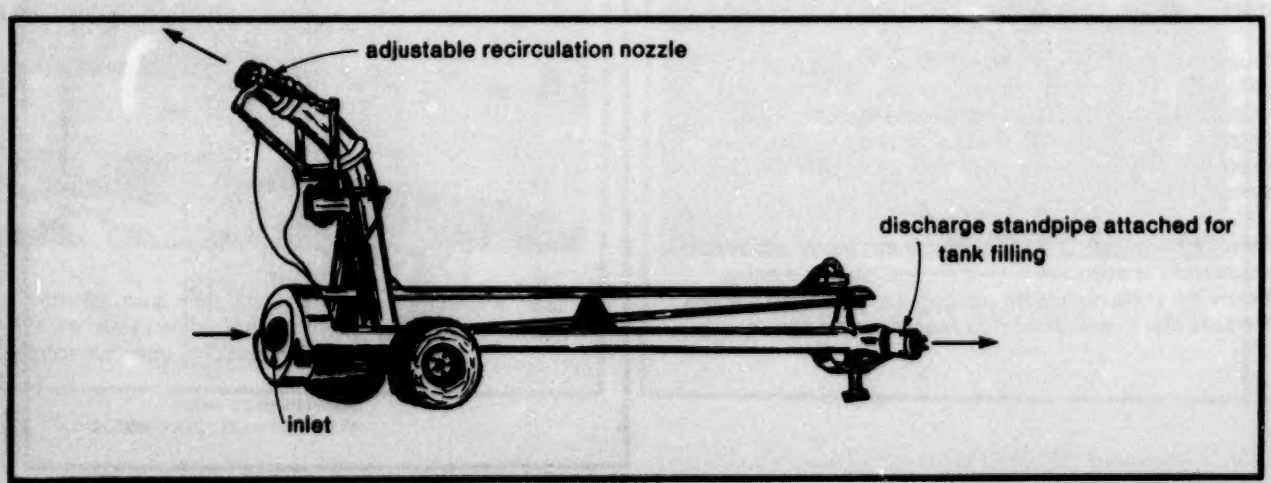


Figure 31 – Typical long reach lagoon pump.

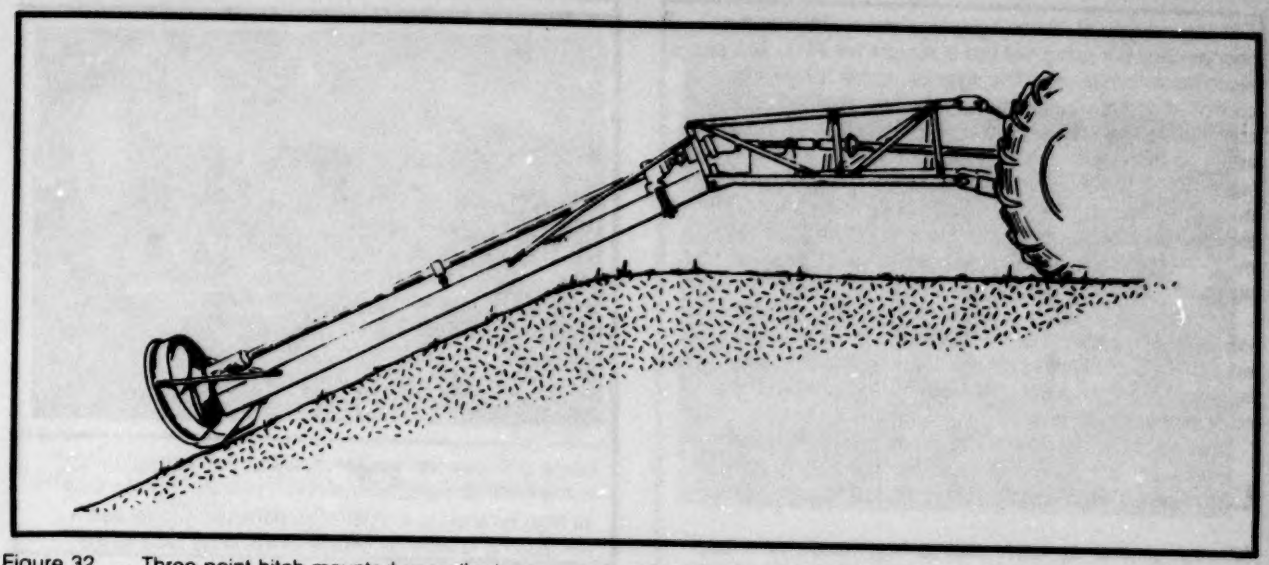


Figure 32 – Three point hitch mounted propellor type manure mixer (courtesy of Pearson Bros. Co., Galva, Ill).

Removal and Transport Methods

Removal from underslat pits

Removal is usually accomplished with a vacuum tanker except where pits are drained to long term storage. Since volume is relatively small and storage time short, agitation requirements are not great, in fact, should be minimized to avoid toxic gas release into the barn.

Note: Extreme caution is required when emptying in-barn storages as the release of toxic gases can cause loss of life. Agitation of the manure should be minimized and the ventilation rate should be increased to its maximum to quickly clear toxic gases from the barn. Barns with solid penning are especially susceptible to gas build-up unless powerful ventilation is provided.

If access ports are provided every 8 m, solids build-up should be minimal.

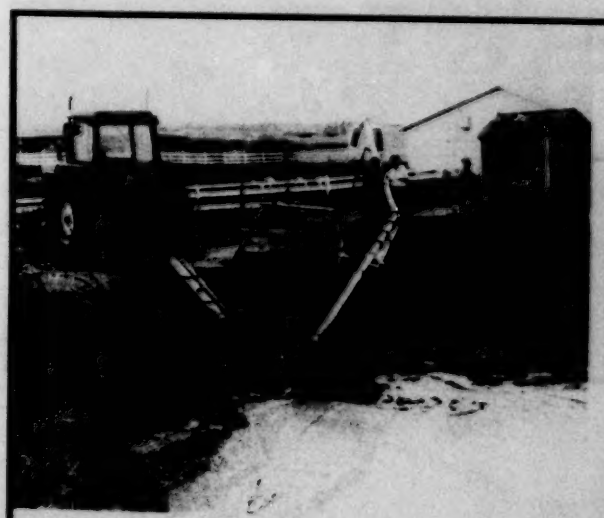
Removal from short-term storage

Pits providing storage for less than three months may require some agitation depending upon their size. The filling and emptying of a vacuum tanker into the storage several times may be sufficient to mix the settled solids. If not, a chopper-agitator pump is required. These pumps are effective in fully enclosed manure tanks such as shown in Figure 19. They are capable of both agitating and filling a tanker wagon at a high rate.

Where a concrete tank is used as a solids settling facility, a chopper agitator pump is a necessity. These pumps have a power requirement of at least 50 hp continuous.

Removal from long-term open storage

Open earthen storages present the greatest difficulty in manure removal. Agitation is best accomplished by large capacity pumping equipment. Several commercial lagoon pumps on the market do a satisfactory job. They come in two designs. The simplest, cheapest agitator is a large diameter propellor device. It has a very high pumping rate and an vigorous action. It is limited in directional agitation and cannot be used for transfer or tank filling. This method of agitation is used in conjunction with vacuum tankers which do the filling and spreading.



Several excellent lagoon pumps are available on the market. This type permits agitation by means of a swivelling nozzle as well as tanker loading via the stand pipe.

The second type of lagoon agitator pump is similar to the chopper agitator pump but has a straight line PTO drive and is much larger in capacity. The agitation nozzle is hydraulically controlled and is very directional, allowing agitation to be concentrated in stubborn lagoon corners. These pumps come with long reach hitches which allow them to be backed into the lagoon providing the power unit has adequate footing and there's a reasonable berm backslope. A concrete ramp entry is excellent as it allows the agitator to enter the lagoon as the manure level drops, thereby maintaining a high degree of agitation right to the end.

While these pumps do an excellent job, they are very expensive. Small to medium operators should consider custom lagoon cleaning as an alternative to the high investment of costs of manure removal and transport equipment.

Land application of manure

Although several alternative uses for hog manure exist, land application as fertilizer is the most practical and cost-effective disposal method for most farmers. With rapidly rising fertilizer rates, producers are looking for better ways of applying manure to land in order to maximize its potential.

Assuming the manure storage is well agitated, many makes of manure tanker wagons are available for removing and transporting manure from storage to the field. These units are either truck mounted or tractor type units. Manure tankers may be vacuum filled or pump filled depending on the storage type, size and method of agitation.

Methods of Manure Application

Broadcast by tanker wagon: The most popular method of application is broadcasting by tanker wagon. It is important that adequate agitation be used in the storage facility so that a reasonably uniform slurry is available for spreading.

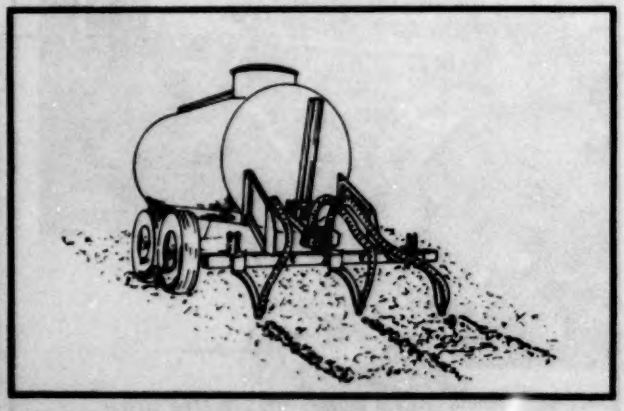
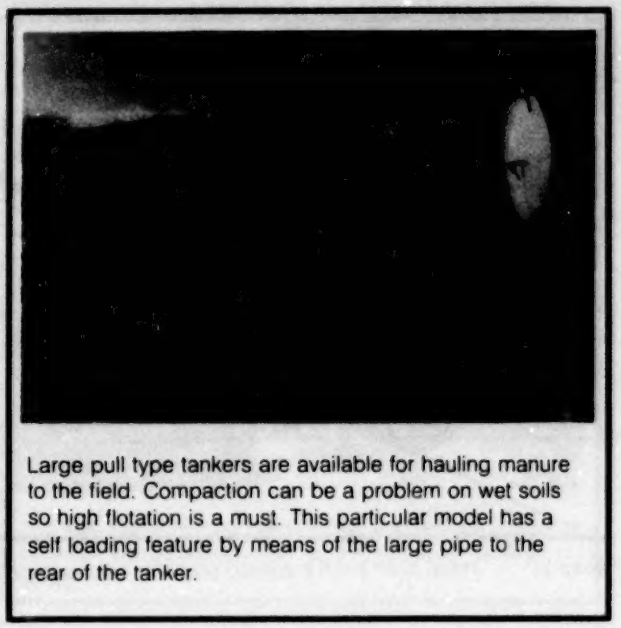


Figure 33 – Tanker fitted with soil injectors.



Large pull type tankers are available for hauling manure to the field. Compaction can be a problem on wet soils so high flotation is a must. This particular model has a self loading feature by means of the large pipe to the rear of the tanker.

Incorporation into the soil within 48 hours (preferably within 8 hours) is recommended to minimize both loss of nitrogen and the nuisance of odor. Direct injection is recommended, however, most available injection equipment is far from ideal. Effective shallow injection at low draft is not possible with existing equipment. The high power requirements and reduced spreading capacity discourage many producers from injecting manure as a standard disposal practice.

The most practical and satisfactory method of incorporation is by tilling immediately after the broadcasting of manure. Total odor control is not obtained but is usually acceptable to neighboring land uses. Broadcasting manure on grass land is recommended only when and where the unincorporated manure will not create a runoff hazard or the odor a nuisance to nearby residences. Manure should not be applied to snow or frozen ground subject to rapid spring runoff into surface water.

Sprinkler irrigation: In situations involving the very large volume storage of low solids liquid hog manure, sprinkler irrigation may be an attractive alternative. The system must be designed to handle the solids content and usually works best where solids can be removed through settling or mechanical means. Figure 34 illustrates a highly mechanized method of spreading liquid manure.

The design and application of sprinkler irrigation systems require detailed planning. Further information can be obtained from an irrigation specialist or agricultural engineer.

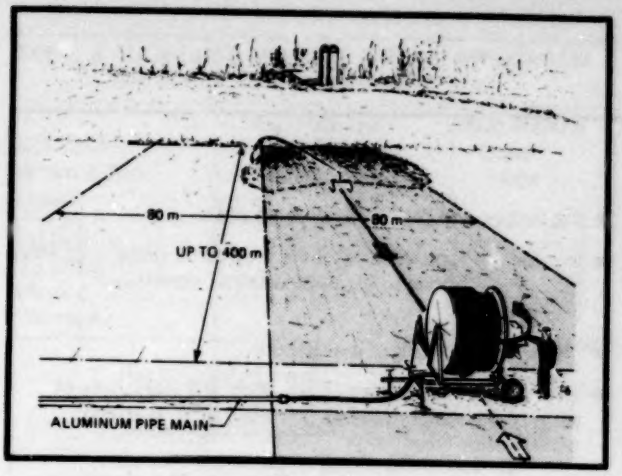
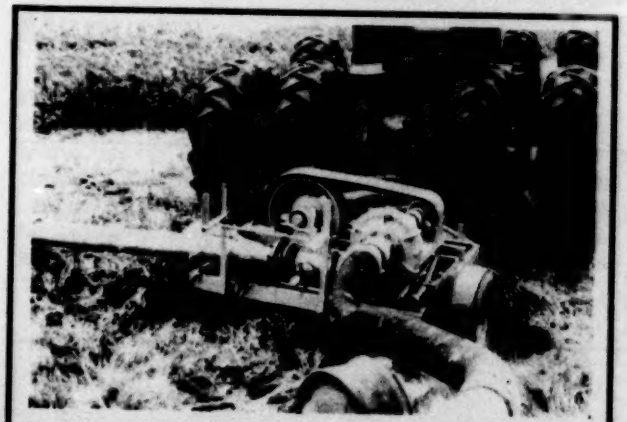
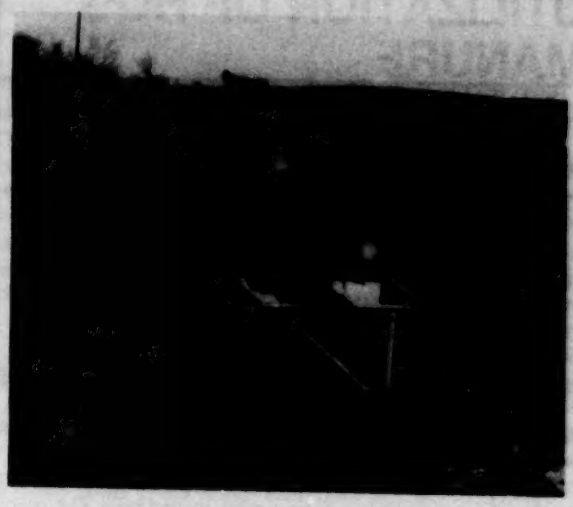


Figure 34 – Hard-hose travelling irrigator, adapted for spreading liquid manure.

Sprinkler irrigation is a relatively new approach to manure application to land. Regular nozzles may result in plugging problems unless the solids are removed and spread by some other method.



Sprinkler irrigation requires an efficient high volume, high pressure pump. Manure solids and foreign objects (rocks, wood, etc.) can easily clog this type of pump.



The manure gun is an irrigation nozzle specifically designed for manure disposal. It will pass all solids normally encountered in a hog manure storage. Spray drift and odors may be a problem with this type of system. This gun is on a skid and may be moved across the field mechanically.

Highly mechanized equipment is available to reduce the labor requirements associated with sprinkler irrigation disposal of manure. The travelling manure gun is one such system available. The large reel pulls the manure gun across the field.

UTILIZATION OF HOG MANURE

Crop Production

A precise determination of the benefit of animal manure to a crop is very difficult since manure is a dynamic organic material continually undergoing biological and chemical transformation. The benefit, therefore, depends upon the composition and nutrient forms present at the time of crop uptake. The nutrient content of the manure is affected by the overall manure handling system. Manure nutrient production data from swine are summarized in Table 6. Potential benefits derived from the manure produced by a livestock operation can be estimated by calculating the total amounts of nutrients produced by the specific farm operation and then multiplying by the value of the nutrients.

TABLE 6. MANURE NUTRIENTS PRODUCED DAILY BY HOGS

Livestock Type	Nutrient Content kg/day		
	N	P	K
Swine (per animal)			
weaner 15 kg (35 lb)	0.007	0.0024	0.005
grower 30 kg (65 lb)	0.013	0.004	0.009
finisher 90 kg (200 lb)	0.041	0.041	0.027
sow gestation	0.028	0.010	0.018
sow & litter	0.104	0.034	0.068

Manure Applications Rates

In estimating the best rate for applying hog manure to a particular soil, consider:

- the texture and fertility level of the soil
- the nutrient requirements of the crop to be grown including cropping program, e.g., summerfallow, continuous cropping, etc.
- the nutrient content of the manure
- local climatic factors which will affect the availability of each of the major nutrients (mineralization, leaching, dentrification rates, etc.)
- the objective of safe, pollution-free recycling of manure nutrients.

The nutrient balance in manure (i.e., the N:P:K ratio) may not be ideal for the specific soil-plant requirements. For example, if sufficient manure is applied to meet the annual requirement for N, the P application may require adjustment. On the other hand, just meeting the phosphorous requirement would, in that case, require a nitrogen supplement. The actual application rate may represent a compromise; the kind of compromise reached should consider local requirements and conditions. Local requirements can best be determined by having manure and soil analysed regularly. Manure application rates in excess of crop requirements result in the uptake of an excessive amount of nitrogen causing crop lodging and the possiblity of contamination of groundwater, particularly when heavily manured fields are subsequently summerfallowed. Acceptable application rates for hog manure are found in Tables 7 and 8. Table 9 is a guide to assist in calculating the acreage required for manure disposal.

TABLE 7. APPLICATION RATES FOR LIQUID MANURE TO SATISFY VARYING CROP NITROGEN REQUIREMENTS
Decay Series: 0.45, 0.15, 0.10, 0.075

N REQUIREMENT OF CROP kg N/ha****	50	75	100	125	150	200
N Concentration % Basis	Litres/ha***					
0.1*	92,000	132,000	185,000	228,000	275,000	365,000
0.2	46,000	69,000	92,000	115,000	137,000	185,000
0.3**	31,000	46,000	62,000	76,000	92,000	124,000
0.4	22,000	35,000	46,000	57,000	69,000	92,000
0.5***	18,000	28,000	37,000	46,000	55,000	73,000
0.6	16,000	24,000	30,000	38,000	46,000	61,000
0.7	13,000	20,000	27,000	33,000	39,000	53,000

* Typical swine manure from storage lagoon
** Typical swine manure from underslat storage
*** Multiply by 0.10 to obtain approximate gal/acre
**** 1 kg/ha = 1 lb/ac

TABLE 8. SUGGESTED MAXIMUM ANNUAL APPLICATION RATES FOR ANIMAL MANURES†

Soil Zone	Solid Manure (tonnes/ha)* Cattle & Hogs	Liquid Manure (L/ha)** Hogs
Brown & Dark Brown		
(a) Dryland	22 – 27	11208 – 44800
(b) Irrigated	56 – 67	33600 – 89700
Black & Grey-Wooded	33 – 45	22400 – 67200

† The suggested maximum application rates for continuous annual applications of manure. Larger quantities could be applied, however, the interval between applications must be increased accordingly.

* Multiply by 0.5 to obtain ton/acre

** Multiply by 0.1 to obtain gal/acre

TABLE 9. SUGGESTED MAXIMUM NUMBERS OF LIVESTOCK PER HECTARE* (ACRE) TO PROVIDE OPTIMUM NUTRIENTS FOR CROP PRODUCTION

Livestock	Brown & Dark Brown Soils Dryland			Black & Grey Wooded Irrigated		
Dairy Cows	4	(1.5)	7	(3)	5	(2)
Beef	15	(6)	30	(12)	20	(8)
Hogs	20	(8)	37	(15)	25	(10)
Laying Hens	370	(150)	740	(300)	500	(200)
Broilers	740	(300)	1500	(600)	1000	(400)

* The above figures assume average losses in storage, handling and for both liquid and solid handling systems.

Refeeding of Animal Manures

With production costs rising rapidly, many producers are looking with interest at various organic waste products for animal feeding. Today's nutritionist thinks in terms of certain quantities of specific nutrients per day. Any product that is an economical source of an animal's nutritional requirement can be considered to be a potential feedstuff. In situations where land availability for manure disposal is limited or where large sources and potential users exist in close proximity (e.g., poultry and feedlots) refeeding of animal manure may be a viable alternative.

Factors such as drug residues, acceptability, digestibility, economics, ease of handling and equipment required must be considered before manure can be incorporated into a feeding program. When all these factors are considered, the recycling of nutrients through animals appears to be an acceptable practice. However, recycling manure for feed has several legal implications. The Plant Products Division (CDA) as well as Food and Drug authorities may have jurisdiction depending on the source, process and end uses involved.

Energy Recovery through Anaerobic Digestion

In many areas of the world, anaerobic digestion has been used for fuel production for a long time. Municipal systems have also utilized this process for its waste-treatment protential. Many farmers have expressed interest in anaerobic digestion owing to rapidly rising energy costs.

Advantages:

- The process is compatible with the environment in that an odorless and free-flowing effluent is produced. Rodents and flies are not attracted to the digested residue.
- The fertilizing nutrients are conserved. The effluent from a digestor contains nutrients in a readily available form.
- A combustible biogas is produced whose primary constituent is methane gas. This biogas has a significant value as fuel.

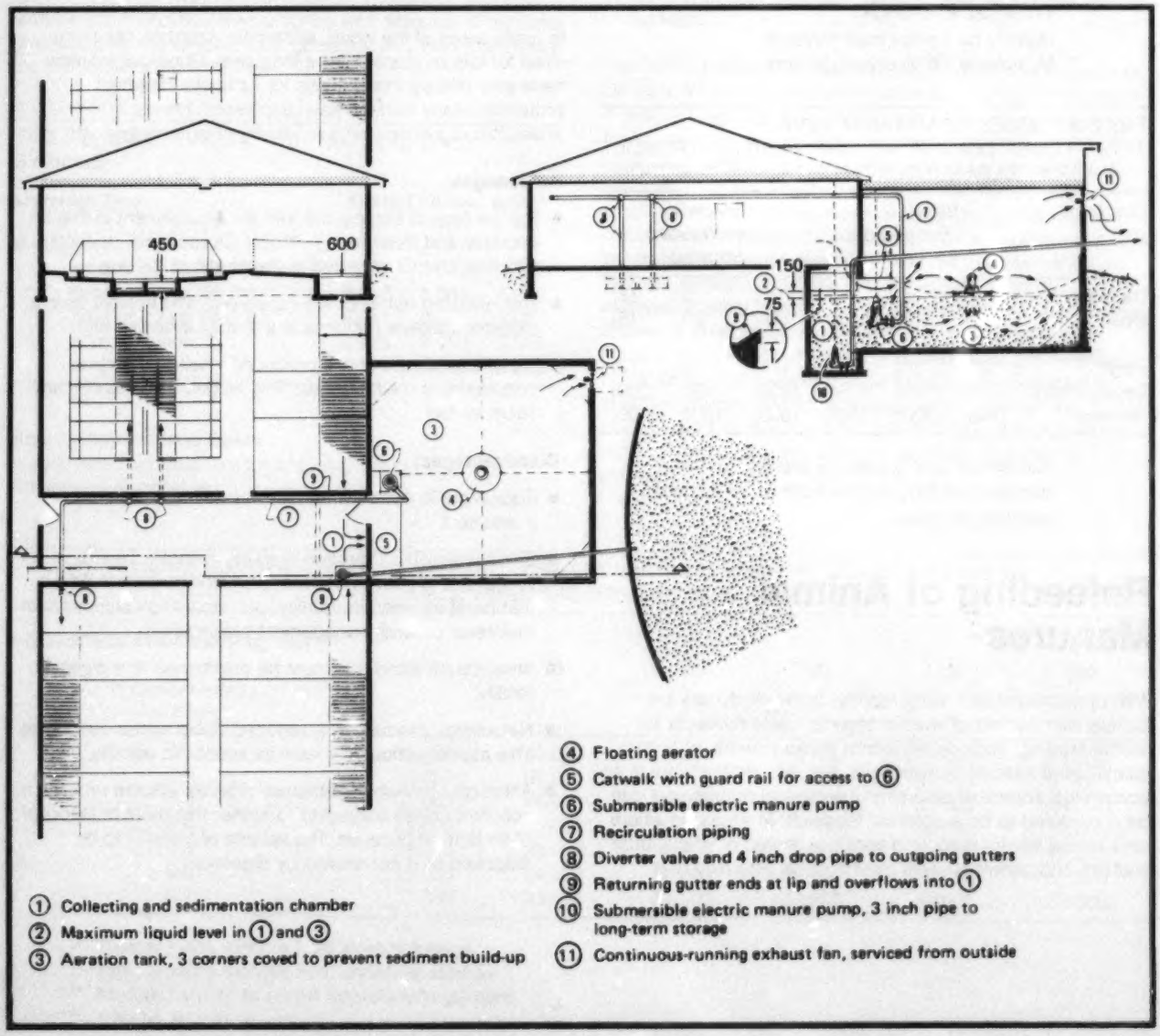
Disadvantages:

- Equipment is complex and involves a high initial investment.
- Since anaerobic digestion is a very complex biological process, it is sensitive to many environmental conditions (temperature, manure quality, pH, etc.). High standards of maintenance and management are required.
- Strict safety standards must be maintained at a digestion facility.
- Net energy production is reduced under winter conditions. This aspect seriously affects its economic viability.
- Although somewhat stabilized, digestor effluent remains a pollutant unless subjected to further treatment or disposal of by land application. The volume of material to be disposed of is not altered by digestion.

SPECIAL TREATMENT PROCESSES

Aeration

Aeration is a proven method of odor control, widely used in municipal waste treatment. Efforts to apply this technology to animal manure handling systems have been attempted with limited success. The objective in each case has been to satisfy the extremely rapid oxygen uptake requirements of the manure by mechanical means in order to maintain aerobic conditions. As previously discussed, the by-products of aerobic decomposition are not noxious, therefore, offering improved environmental and housing conditions in and around piggeries.



① Collecting and sedimentation chamber
② Maximum liquid level in ① and ③
③ Aeration tank, 3 corners coved to prevent sediment build-up
④ Floating aerator
⑤ Catwalk with guard rail for access to ⑥
⑥ Submersible electric manure pump
⑦ Recirculation piping
⑧ Diverter valve and 4 inch drop pipe to outgoing gutters
⑨ Returning gutter ends at lip and overflows into ①
⑩ Submersible electric manure pump, 3 inch pipe to long-term storage
⑪ Continuous-running exhaust fan, serviced from outside

Figure 35 – Flushed lip, 'hairpin' gutter system with continuous mechanical aeration to deodorize the flushwater.

Reputable manufacturers rate their aerators by standard tests to determine their oxygenating capacity, with ratings expressed in kilograms of oxygen per hour dissolved in fresh water. Comparative efficiencies are even more meaningful when oxygenation capacity is divided by the required electrical energy consumption, expressed as kg of O_2/kWh. Some specialized equipment manufacturers, hoping to improve on established designs, have developed a bewildering array of aeration equipment using air compressors, diffusers, turbines, aspirated propellors, etc. Unfortunately, it is easy to be misled by manufacturers who make unrealistic claims for their equipment. The equipment sold could be undersized for the job and odor control will not be achieved.

Aerators may be sized for partial or total aeration, depending on system requirements. Total aeration is needed where the entire quantity of manure produced must be treated to eliminate odors for land spreading. This is an expensive alternative, to be considered only where neighbors or urban encroachment threaten to force an established swine enterprise out of the community.

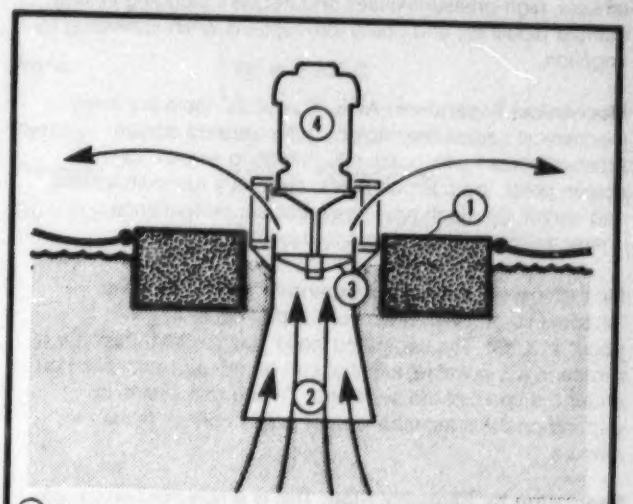
Partial aeration applies where deodorized flush water is to be processed from part of the manure produced. Table 10 adapted from the B. C. Ministry of Agriculture and Food gives recommended oxygenation capacities.

TABLE 10. OXYGEN REQUIRED (KG/H) FOR SWINE MANURE AERATION

Operation Type	Partial Aeration		Total Aeration
	Surface mixing	Full mixing	
100 sows, farrow to wean	2.5	5	10
Grow-finish, from 100 sows	2.5	5	10
100 sows, farrow to finish	5	10	20

Another hidden cost of aeration treatment is the loss of nitrogen fertilizer value from the manure. Research in Ontario indicates that "total aeration" in warm weather resulted in a 62% nitrogen loss between fresh manure and land spreading as compared with 25% estimated for manure stored and handled without aeration. It is clear that total aeration is a last resort, where going out of business is the alternative.
The following approaches have been taken and are summarized for the interest and application of hog farmers.

Aerobic lagoons: Theoretically, when a storage facility has a sufficiently high surface area to volume ratio, the oxygen demand can be satisfied by natural diffusion of oxygen across the air-water interface. In practice, this approach is not practical owing to the extremely high organic matter concentration of hog manure requiring an unreasonably large lagoon. Our climatic conditions also prevent oxygen transfer during the winter months because of the ice cover.
Mechanical aeration of lagoons has been attempted with very limited success. Aeration methods include various floating devices (see Figure 36) plus perforated air lines placed in the lagoon. Aeration which is supposedly adequate to maintain aerobic conditions in the lagoon, in practice may be inadequate because of climatic conditions during the winter and inadequate mixing of the lagoon contents. Yard odors can actually be increased by aeration as a result of the disturbance and scrubbing action involved, particularly during the early portion of the summer season.



① Ring float, tethered 4 ways with cables to the tank walls
② Draft tube
③ Propellor and slinger-ring on motor shaft
④ Electric motor, 0.75 to 5.6 kW output rating

Figure 36 – Floating propellor-type surface aerator.

High maintenance and operation costs are an inherent problem with lagoon aeration so should be given careful consideration by hog operators.

Oxidation ditch: Controls odor in piggeries, however, the reliability, operating costs and foaming problems virtually rule out the oxidation ditch as a viable alternative for odor control.

Liquid composting: This approach involves the high rate aeration of a small portion of the total manure production for use as a flushing medium, similar in design to Figure 35. The objective is to produce a high quality, odor-free and warm liquid for this use. Since total treatment is not attempted, the operating costs are much more realistic, and when combined with liquid/solids separation, may offer a somewhat expensive and sophisticated alternative. Its viability depends upon the value placed on the effluent quality, whether or not nutrient loss occurs with the process and the end use made of the liquid and solid fractions.

Solids-Liquid Separation

This processing step has received much recent attention. One could ask why one should separate the solids and liquids, when this will require two handling systems instead of one? A practical answer is that many farms already have a loader and manure spreader anyway, and the volume of

separated solids is actually quite insignificant compared with the liquid part. However, the coarser solid manure particles create major problems in liquid manure handling. These include sludge build-up in the bottom of storages and tankers, high pressure-losses and frequent plugging in long manure pipelines, and costly interruptions when spreading by irrigation.

Mechanical Separators: As with aerators, there are many mechanical separators, including the brushed screen, brushed screen with press-rolls, vibrating screen, rotary screen press, porous belt press, stationary rundown screen, and centrifuge. Each type has particular performance characteristics too numerous to describe here.

Mechanical separators are expensive; for example the 'brushed screen with press-rolls' type (Figure 37) sells for about $13,000. The separated 'solid' fraction from this type of device is a 'stackable' mix that can be more or less 'piled up' under the spout of the separator. Throughput seems to depend on the removable coarse solids content of the manure.

Separation by Sedimentation: This is a non-mechanical way to separate manure solids from liquids. One very effective sedimentation system used in Manitoba consists of a covered concrete settling chamber just outside the swine barns, followed by an earthen storage (see Figure 38).

A more economic approach is to use a two-stage earthen storage facility although the sedimentation effectiveness may not be quite as high as the concrete settling chamber.

Another aspect of this sedimentation process is that phosphorus (P) tended to concentrate in the settled sludge, whereas total nitrogen (N) tended to remain distributed in both parts. This fact should be noted when setting application rates for effective use of both parts as balanced fertilizer. In other words, it would be quite easy to oversupply the phosphorus fertilizer requirements unless the sludge is thinly spread.

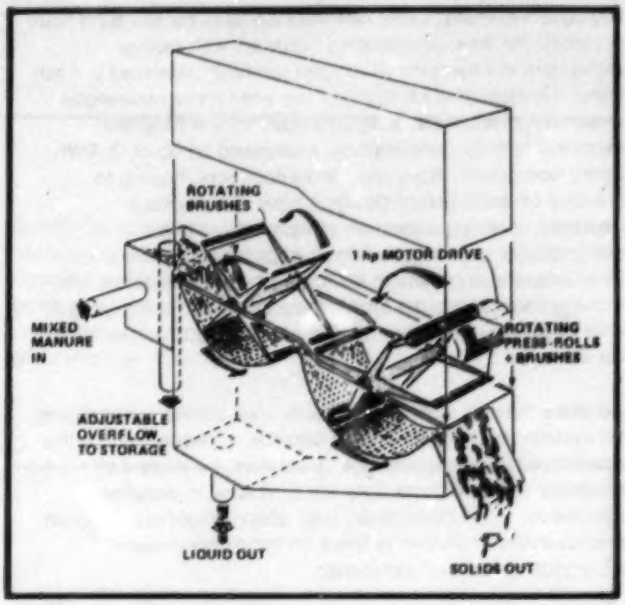


Figure 37 – Liquid/solid separator; brushed screen with press rolls.

The system provides an obvious economic advantage by requiring only one-fifth of the long-term storage volume to be expensive covered concrete, and four-fifths a relatively cheap clay-lined pond. The sedimentation tank could be located partly under one of the barns as long as the gas trap is retained. Where a two-stage earthen storage is planned, the solids storage should be designed for one-third of the manure volume for the time period required.

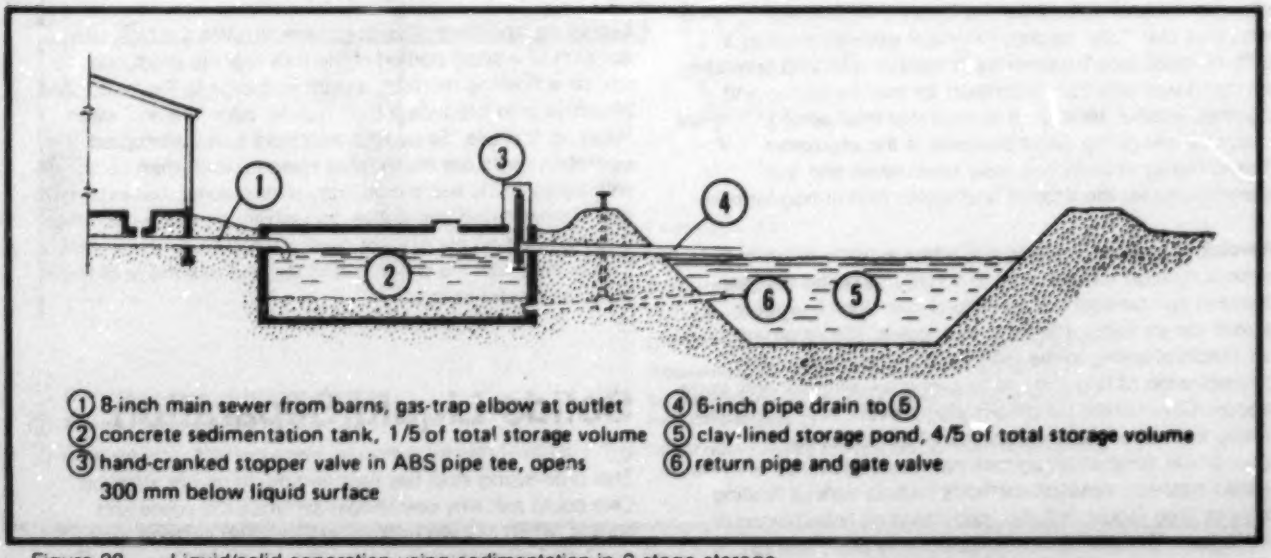

1
2
3
4
5
6
① 8-inch main sewer from barns, gas-trap elbow at outlet
② concrete sedimentation tank, 1/5 of total storage volume
③ hand-cranked stopper valve in ABS pipe tee, opens 300 mm below liquid surface
④ 6-inch pipe drain to ⑤
⑤ clay-lined storage pond, 4/5 of total storage volume
⑥ return pipe and gate valve

Figure 38 – Liquid/solid separation using sedimentation in 2-stage storage.

METRIC CONVERSION TABLES

Length:	1 mm = 0.0394 in. 1 m = 3.281 ft 1 km = 0.621 miles	Mass:	1 kg = 2.205 lb 1 t = 1.102 ton
Area:	1 m^2 = 10.76 ft^2 1 ha = 2.471 acres	Density:	1 kg/m^3 = 0.0624 lb/ft^3
Volume:	1 L = 0.220 gal (Imp)1 m^3 = 35.31 $ft^3$1 m^3 = 1.308 yd^3	Pressure:	1 MPa = 145 $lb/in.^2$(psi)
		Fluid Flow:	1 L/s = 2.12 ft^3/min (cfm)

FURTHER INFORMATION AVAILABLE FROM

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